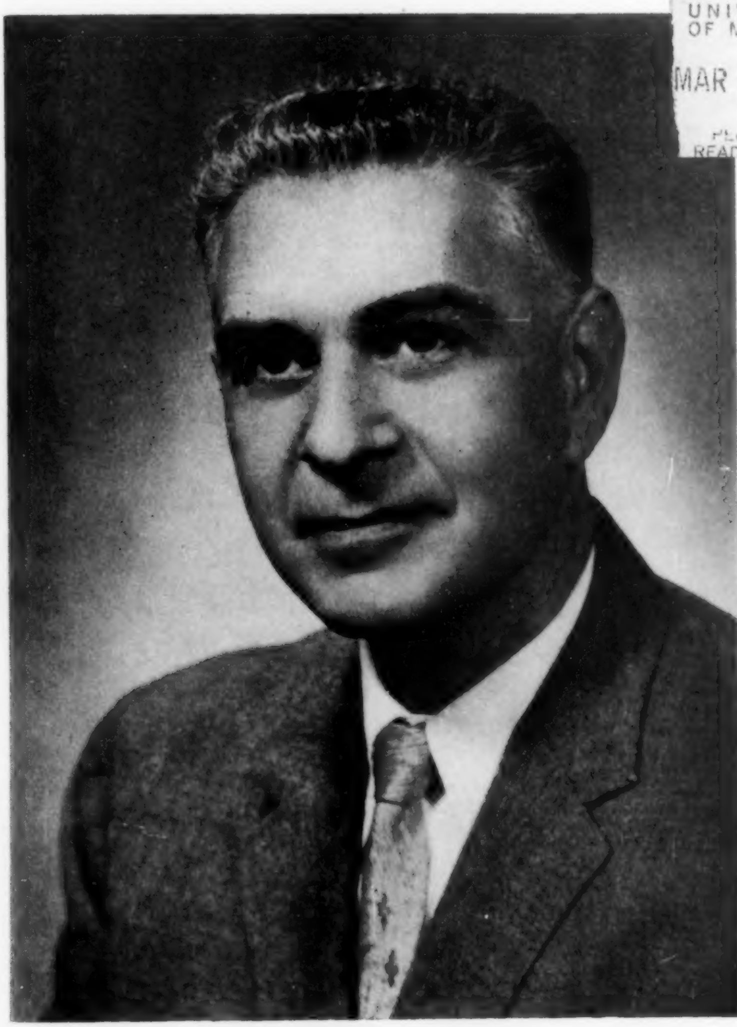
SCIENCE EDUCATION



NATHAN S. WASHTON

VOLUME 42 FEBRUARY, 1958 NUMBER 1

SCIENCE EDUCATION

THE OFFICIAL ORGAN OF

The National Association for Research in Science Teaching
The National Council for Elementary Science
Association for the Education of Teachers in Science

CLARENCE M. PRUITT, EDITOR
University of Tampa
Tampa, Florida

Manuscripts and books for review as well as all communications regarding advertising and subscriptions should be sent to the Editor.

SCIENCE EDUCATION: Published in February, March, April, October, and December.

Subscriptions $5.00 a year; foreign, $6.00. Single copies $2.00; $2.50 in foreign countries. Prices on back numbers furnished upon request.

Publication Office: 374 Broadway, Albany, New York.

Entered as second-class matter at the Post Office at Albany, New York, February 13, 1939, under the Act of March 3, 1879.

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SCIENCE EDUCATION

VOLUME 42 FEBRUARY, 1958 NUMBER 1

NATHAN S. WASHTON

Doctor Nathan S. Washton had the honor of serving as the Twenty-fifth President of the National Association for Research in Science Teaching and is the recipient of the Ninth Science Education Recognition Award. Since becoming a member of the National Association for Research in Science Teaching in 1950, Dr. Washton has been one of its most active and valued members. No one has shown a finer professional spirit, participated more wholeheartedly in the activities of N.A.R.S.T., or had the welfare of the organization always first. Such loyalty and spirit of cooperation has been most pleasing and heart-warming to we older members of the Association. Truly a handful of younger men (whom we shall not name) but among whom Dr. Washton's is typical have been the guiding spirits of the organization. In the hands of these younger men, the organization is fulfilling the dreams of its organizers, men such as Curtis, Powers, Webb, Craig, Pieper, Palmer, Glenn, Riedel, Gruenberg, Watkins, the late Drs. Eikenberry, Downing, Caldwell, Underhill, Whitman, Hunter, Hurd. As with these older N.A.R.S.T. members who dedicatedly devoted their lives to the improvement of science teaching, N.A.R.S.T. is fortunate in having younger members with this kind of idealism. To reach the heights attained by these older members will not be an easy task. But it can be done and there will be a selective few who do. Diverse as the philosophies of these older members may have seemed to be, they had some characteristics in common—a fine professional spirit, a sincere desire to improve science teaching at all levels, and a loyalty to N.A.R.S.T. of the first order. May their successors exemplify the same characteristics. Dr. Washton does possess these qualifications. As the original sponsor of Dr. Washton's membership in N.A.R.S.T., it has always been a source of pride to note his development as a most loyal, effective contributor to N.A.R.S.T. progress.

Dr. Washton was born in New York City November 9, 1916, the son of Max and Lena Washton. His grade school and high school education was received in the New York City schools. He received a B.S. degree from New York University in 1939; an M.A. degree from Teachers College, Columbia University, in 1941; and an Ed.D. degree from New York University in 1949.

Dr. Washton married Sylvia Salitsky December 25, 1944. Mrs. Washton graduated cum laude, Phi Beta Kappa from Hunter College, majoring in Sociology. She had some graduate work at Columbia University. The Washtons are the parents of three daughters: Gale, 12 years old; Ruth, 9 years; and Laura, 4 years. They live at 130–02 227 Street, Laurelton, Long Island, New York, where each is very active in civic affairs.

Teaching experience of Dr. Washton includes: Assistant in biology, New York University, 1938; teacher of science and mathematics, Newark, New Jersey, Public Schools, and Chairman of Science and Director of Guidance, Newark Junior College, 1939–42; Head of science and mathematics department, Dwight School, New York City, 1945–46; Chairman of General Science and Director of Guidance, Rutgers University, Newark, New Jersey, and also

Visiting Professor Upsala College, East Orange, New Jersey, 1949–50; Coordinator of Science Education, Queens College, Flushing, New York, since 1950; Visiting Professor of Education, University of Puerto Rico, Summer, 1948. For 15 summers following 1934, Dr. Washton served as counselor, head counselor, and director of summer camp for children. During his tenure at Queens College, he has taught the educational foundations course, the methods of science courses for elementary and secondary teachers, and also supervised student teachers in science and mathematics. He has served as consultant to the following groups: Board of Examiners for science teaching licenses for the Board of Education of New York City; Bureau of Curriculum Research of the New York City Board of Education; the Library of Science; Nassau-Suffolk Chapter of the New York Association for Nursery Education; a number of school systems in New York, Michigan, and Georgia.

During 1942–45, Dr. Washton served in the U. S. Air Force, advancing from the rank of private to Captain. He was Director of Technical Training, Randolph Field, Texas. He received commendation for organizing and supervising 30 communication centers throughout the United States. He had combat service in the China-India-Burma areas. For this activity, Dr. Washton received numerous military medals. During 1941–42 he was awarded a Harvard Scholarship on Junior College Education but could not accept because of military service.

Memberships in organizations include: National Association for Research in Science Teaching, American Education Research Association, American Association of University Professors, Central Association of Science and Mathematics Teachers, National Science Teachers Association, American Association for the Advancement of Science, Master Mason, Empire City Lodge, 206, New York. He is a Fellow in the AAAS and listed in *Who's Who in American Education.* In N.A.R.S.T. he has served as Chairman of the College Committee, Vice-Chairman of the Second Annual Review, Executive Committee member (1955–56) and Vice-President (1956–57).

Publications include some 30 articles in *Science Education, School Science and Mathematics, Junior College Journal, Journal of Higher Education, Bulletin of the Association of American Colleges, School Activities, Science,* and *Review of Educational Research.* The title of his Master's thesis completed at Teachers College, Columbia University (1941) was: "Reconstruction of the Curriculum for General Education." The title of his doctoral study completed at New York University (1949) was: "A Syllabus in Biology for General Education." Dr. Washton has served as Editor of the *Man and His World* series (science books for secondary students) published by Henry Schuman (now Abelard-Schuman), New York City. He is co-author of *Step Science Test for College Students* published by Educational Testing Service, Princeton, New Jersey.

His point of view or philosophy of science teaching may be summarized as follows:

> Science Teaching should be functional and related to the personal and social needs of the individual and the community.
>
> An understanding of science requires an understanding of the social implications of science and how they affect man in his changing environment. In this way, intelligent citizens can learn science for better living.
>
> There is a need for teaching the historical development of the great scientific ideas with the view of developing scientific methods and scientific attitudes. It is also possible to teach men and women to utilize the problem solving skills that are available from the research work of scientists.
>
> Emphasis should be placed on helping students think more scientifically and creatively rather than the mere acquisition of basic facts as ends in themselves. Facts are needed to arrive at generalizations or broad principles and laws and the degree of the nature of this type of learning is related to one's emotional makeup and scientific attitudes. We must learn more ourselves in this area.
>
> One of the major problems facing scientific

industries and the teaching profession is the recruitment of prospective science teachers and scientists. Unless highly qualified and competent science teachers are obtained, we cannot hope for a better teaching program which will inspire a larger number of young people to consider science as a career. We must have eager and top-notch science teachers to develop top-notch scientists. (This expressed view of Dr. Washton has been affirmed by President Eisenhower's recommendations of Congressional aid to promote and encourage more interest in science and mathematics careers.)

1. Science and the teaching of science are dynamic. Scientific advances in the history of our civilization make this concept evident.

2. Research in the teaching of science is still in the stages of embryological development. As new knowledge is obtained and applied intelligently to the teaching of science, more effective learning will occur. Better instruments for evaluating learning are being developed. As experimental procedures and materials are introduced in the teaching of science, so will the understandings, skills, and attitudes be developed more adequately.

3. At present, there cannot be one method of teaching science which is universally accepted as the best method for all teachers in everyday classroom instruction. At best, an inspiring science teacher should be familiar with all available techniques and the most up to date knowledge and be able to use them where they are most productive for various kinds of learnings.

4. A science teacher is responsible for encouraging and training the best future scientists who can make worthy contributions to our individual citizens and to our society for peace and security, better health, and prosperity.

5. The science teacher assumes responsibility for teaching science for general education. In our space-travel age, intelligent citizens need to be well informed in understanding science and its impact upon all societies.

6. The science teacher today should also help people learn how to make better adjustments to our changing environment.

7. Science is international and knowledge should be made available to all people who are interested in using it for advancing a better and peaceful life in our universe.

8. Science teaching should stress humility and a search for knowledge where freedom of thinking promotes creativity.

9. Science teaching can help develop the major ideas that are related to analytical reasoning where prejudice is overcome by open-mindedness and a willingness to accept new ideas.

10. A science teacher is always a student. He can learn from students as well as from reading, studying, research, and other experiences. When a teacher ceases to learn, he should cease to teach. Where there is no learning, there is no teaching.

It has been announced very recently by the Board of Higher Education which controls and administers all of the municipal colleges in New York City that Dr. Nathan S. Washton has been requested to conduct a study on the needs for the establishment of City Community College in the Borough of Queens. The college would be a two-year college emphasizing terminal, vocational education with one program in general education. For this study, Dr. Washton has been relieved of some of his teaching duties at Queens College.

As important as have been Dr. Washton's contributions to the improvement of science teaching during the last decade, it is to be expected that his contributions in the next two decades will be even more significant. So it is with great satisfaction that Dr. Nathan S. Washton is made recipient of the Ninth Science Education Recognition Award.

CLARENCE M. PRUITT

BENJAMIN C. GRUENBERG

Although coming too late to include in his biographical sketch in the April issue of *Science Education,* the following comments made by President J. L. Morrill of the University of Minnesota on the presentation of the University of Minnesota Outstanding Achievement Award to Benjamin C. Gruenberg on June 5, 1957 are an appropriate addenda:

We appreciate the presence of this friendly company, assembled in honor of Dr. and Mrs. Benjamin C. Gruenberg of New York City.

Although we meet informally, this is a very special occasion—unusual in our calendar of University ceremonies, because specially arranged.

Last year, the Regents of the University, upon the recommendation of the Senate Committee on Honors and the Administrative Committee of the University, voted to present the University's Outstanding Achievement Award to Dr. Benjamin C. Gruenberg. This award is reserved for former students of the University who have achieved high distinction in their chosen professions and fields of activity.

And Dr. Benjamin Gruenberg has done just this, and has brought honor and reflected lustre to the University thereby. Dr. Gruenberg was born in Bessarabia, you may be interested to know. That is a long way from Minnesota—and I hope he will tell us how he came to find his way to this state and our University.

But get here, he did. Here, Dr. Gruenberg received his Bachelor of Science Degree in 1896.

From Columbia University, later on, Dr. Gruenberg gained three important advances. He received there his Master of Arts degree in 1908 and his Ph.D. degree in 1911. But the most important of the three, I gather from biographical material I've seen, is that he found Mrs. Gruenberg there, for she graduated from Teachers' College in 1910.

From some points of view, this Outstanding Achievement Award—and I know Dr. Gruenberg would wish me to say this—should be presented *jointly* to Dr. *and* Mrs. Gruenberg. I'm sure that the only reason why this wasn't proposed is that Mrs. Gruenberg was never a student here—which we wish she had been!

Together, Dr. and Mrs. Gruenberg have attained a most distinguished record of achievement. They've not been marriage partners only—although successful married partners indeed, I gather from the records of their children—but they've been successful in many other common undertakings.

Dr. Gruenberg was first a teacher of biology. Very early his ideas relating to high school curricular problems attracted important attention. He was concerned with the necessity for instruction in personal hygiene and sex education, for example. Slowly—all too slowly in those days, I surmise—support from teachers, parents and social workers came his way.

But later there came a time when the United States Public Health Service, the Child Study Association of America, social service agencies, youth organizations—all sorts of groups—began to rely on Dr. Gruenberg—and upon Mrs. Gruenberg, too—because for a good many years she *was* the Child Study Association of America, I am told.

This partnership of the Gruenbergs now has very deep roots in our society. Through their articles, lectures, research and consultations, America itself has become a better place in which to live. It is interesting to recall that Dr. and Mrs. Gruenberg were instrumental in establishing *Parents' Magazine,* at one time owned, in part, by our own University of Minnesota, and a factor in the support of our Institute of Child Welfare.

Although especially invited, Dr. and Mrs. Gruenberg couldn't come here a year ago to receive the University's award at the Annual Alumni Banquet. But our ingenious and efficient Mr. William Nunn, who, with the members of the Senate Functions Committee, manages these affairs, told Dr. Gruenberg that he would contrive a presentation ceremony any time that Dr. Gruenberg could find it convenient to be in Minneapolis.

And so, at this rather intimate luncheon today, in this select company of the friends and admirers and relatives of both Dr. and Mrs. Gruenberg, it it my happy privilege, on behalf of the Board of Regents, to present this award. Let me say also that we are very happy that Dr. and Mrs. Frederick P. Gruenberg of Philadelphia, and Mrs. Eugenie Harris of Minneapolis could be with us to share in the felicitations to these distinguished members of their family circle.

The citation reads as follows:

The Regents of the University of Minnesota
As a Token of High Esteem and
In Recognition of Noted Professional
Attainment by

Benjamin C. Gruenberg
Distinguished Graduate of the
University of Minnesota
Biologist, Writer, Lecturer, and
Research Director

Long Famed as a Prominent Figure in the Field
of Family Life Education
A Pioneer in the Introduction of Hygiene
to the High School Curriculum
Respected in the Field of Psychology,
Public Health and Medicine

Deem Him to Be Worthy of Special
Commendation for Outstanding Achievement
Conferred on
June Fifth, Nineteen Hundred and Fifty-Seven

WILLIAM LEWIS EIKENBERRY

It is with deep regret that we record the passing of William Lewis Eikenberry on December 20, 1957 at his home in Polo, Illinois. His wife Florence Shaw preceded him in death April 13, 1953. A son, Robert S. Eikenberry of the Department of Aeronautical Engineering, University of Notre Dame, Notre Dame, Indiana, survives. Born July 12, 1871 in Waterloo, Iowa, Dr. Eikenberry was the oldest living member of the National Association for Research in Science Teaching. He was a Charter and Life member of N.A.R.S.T. and served as its first president, 1928–30. As previously recorded in *Science Education,* "it was his letter to some 35 educators that got together the first group out of which N.A.R.S.T. was born."

Dr. Eikenberry was the recipient of the Second Science Education Recognition Award. An attendant at the 1956 N.A.R.S.T. meeting in Chicago, he maintained his active professional interest in N.A.R.S.T., *Science Education,* and the teaching of science until the very end.

Science teachers at all levels owe Dr. Eikenberry a tribute of gratitude for his distinguished leadership in science education through writings, professional activities, and inspirational teaching. Truly a Sequoia in the science teaching field has fallen.

A more complete biography of Dr. Eikenberry will be found in the October, 1956, issue of *Science Education.*

CLARENCE M. PRUITT

PROGRAM OF THIRTIETH ANNUAL MEETING OF THE NATIONAL ASSOCIATION FOR RESEARCH IN SCIENCE TEACHING

HOTEL CLARIDGE, ATLANTIC CITY, NEW JERSEY
FEBRUARY 15–17, 1957

OFFICERS OF THE NATIONAL ASSOCIATION FOR RESEARCH IN SCIENCE TEACHING

President: DR. WALDO W. E. BLANCHET, Dean, Fort Valley State College, Fort Valley, Georgia

Vice-President: DR. NATHAN S. WASHTON, Coordinator of Science Education, Queens College, Flushing 67, New York

Secretary-Treasurer: DR. CLARENCE M. PRUITT, University of Tampa, Tampa, Florida

Executive Committee: DR. THOMAS FRASER, *Chairman,* Department of Science, Morgan State College, Baltimore, Maryland; DR. WILLIAM C. VAN DEVENTER, Department of Biology, Western Michigan University, Kalamazoo, Michigan

Program arranged by
NATHAN S. WASHTON
Queens College, New York

FRIDAY, FEBRUARY 15

BOARD ROOM

STUDIES ON METHODS COURSES FOR SCIENCE TEACHERS
THOMAS FRASER, *Chairman*

A.M.

9:00–9:30 Registration and Greeting

9:30–9:50 "Criteria for a Special Methods Course in Physical Science Education for New Jersey Secondary School Science Teachers," Fred T. Pregger, New Jersey State Teachers College, Trenton, N. J.

9:50–10:10 "Criteria for a General Methods Course in Science Education for New Jersey Secondary School Science Teachers," Irwin H. Gawley, New Jersey State Teachers College, Montclair, N. J.

10:10–10:30 "Criteria for a Special Methods Course in Biological Science Education for

New Jersey Secondary School Science Teachers," Frank X. Sutman, New Jersey State Teachers College, Paterson, N. J.

10:30–10:45 Discussion

STUDIES IN ELEMENTARY SCIENCE AND TEACHER EDUCATION

GEORGE G. MALLINSON, *Chairman*

10:45–11:05 "A Critical Examination of the Use of Analogy in Science Writings for Children," Nelson F. Beeler, State University Teachers College, Potsdam, N. Y.

11:05–11:25 "A Way of Developing Children's Understanding of Ecology," Beth Schultz, State Teachers College, Lock Haven, Pa.

11:25–11:45 "The Development and Evaluations of an In-Service Education Program in Elementary School Science," Ward L. Sims, Washburn University of Topeka, Topeka, Kansas

11:45–12:05 "Development and Status of Teacher Education in the Field of Science for the Elementary School," William D. Chamberlain, Detroit Public Schools, Detroit, Michigan

12:05–12:20 Discussion

12:20 Lunch

FRIDAY, FEBRUARY 15

BOARD ROOM

STUDIES ON PROBLEMS OF TEACHING SCIENCE IN SECONDARY SCHOOLS

WALDO W. E. BLANCHET, *Chairman*

P.M.

2:00–2:20 "The Ability to Identify and Evaluate Assumptions in Eighth Grade General Science," Elizabeth A. Simendinger, Uniondale High School, Uniondale, N. Y.

2:20–2:40 "Adapting Science Instruction in New York City Junior High Schools to the Needs of Puerto Rican Pupils," Carmen S. Sanguinetti, The Puerto Rican Study, Board of Education, New York, New York

2:40–3:00 "The Relative Difficulties of Different Types of Items on Tests for High School Science," Jacqueline Buck Mallinson, Western Michigan College, Kalamazoo, Michigan

3:00–3:20 "A Film Slide Test to Measure Ability to Apply Scientific Method in the Area of Mechanics in High School Physics," Harvey J. Goehring, Jr., Penn. Township Senior High School, Verona, Penn.

3:20–3:40 "Some Learning Differentials Among Students Under Three Different Teaching Conditions," Herbert A. Smith and Kenneth E. Anderson, University of Kansas, Lawrence, Kan.

3:40–4:00 "The Mathematical Processes Needed in Learning High School Chemistry and High School Physics," J. Bryce Lockwood, Highland Park Junior College, Highland Park, Michigan

4:00–4:20 "A Study on the Place of Principles in Junior High School Mathematics," John A. Brown, State University Teachers College, Oneonta, New York

4:20–4:40 "High School Course Offerings, Enrollments, and Science Teachers," James A. Rutledge, University of Nebraska, Lincoln, Nebraska

4:40–5:00 "A Comparative Study of Greater Student Participation in Laboratory Work in High School Chemistry," Steven J. Mark, Kent State University, Kent, Ohio

5:00–5:20 "Social Responsibility of Science Education," Robert J. G. Barlow, Ewing Junior High School, Trenton, N. J.

5:20–5:35 Discussion

7:00 Dinner at Hackney's Restaurant

SATURDAY, FEBRUARY 16

BOARD ROOM

STUDIES ON PROBLEMS OF TEACHING COLLEGE SCIENCE COURSES FOR GENERAL EDUCATION

NATHAN S. WASHTON, *Chairman*

A.M.

9:00–9:20 "A Proposed Science Program for General Education at Castleton Teachers College," Richard A. Sleeman, Kent State University, Kent, Ohio

9:20–9:40 "The Development of a General Education College Chemistry Course," L. A. Arnold, Winona State Teachers College, Winona, Minn.

9:40–10:00 "The Nature of Physical Science Education for Pre-Theological Students at Lutheran Colleges," Erich Hopka, St. John's College, Winfield, Kansas

10:00–10:20 "Three Classroom Procedures" (Mechanism in Biology), Mervin E. Oakes, Queens College, Flushing, N. Y.

10:20–10:40 "A Technique for the Selection of Laboratory Experiments for a College General Education Physical Science Course," David A. Hilton, Wayne State University, Detroit, Mich.

10:40–11:00 "An Analysis of the Mathematical Concepts Necessary for a College Physical Science Course," Herbert L. Hannon, Western Michigan University, Kalamazoo, Mich.

11:00–11:20 "Personality Aspects Related to Misinformation About Sex Among College Students," Dolores E. Keller, Fairleigh Dickinson University, Teaneck, N. J.

11:20–11:40 "Present Status and Problems of One Type of Grade-Placement Research," John G. Read, Boston University, Boston, Mass.

11:40–11:55 Discussion

OCEAN DINING ROOM

P.M.

12:30 Luncheon

Speaker: Gerald S. Craig, Professor of Natural Science, Teachers College, Columbia University

Topic: "Trends in Science Education for Children During the Past Century"

SATURDAY, FEBRUARY 16

BOARD ROOM

REPORTS OF RESEARCH IN SCIENCE EDUCATION

WILLIAM C. VAN DEVENTER, *Chairman*

P.M.

2:40–2:50 Progress of the Committee on Ele- of Research in Science Education, Ellsworth S. Obourn, U. S. Office of Education

2:40–2:50 Progress of the Committee on Elementary Science, Lillian H. Darnell, Des Moines, Iowa

2:50–3:00 Progress of the Committee on Secondary Science, George T. Davis, University of Maine, Orono, Maine

3:00–3:10 Progress of the Committee on College Science, Edward K. Weaver, Atlanta University, Atlanta, Georgia

3:10–3:30 "A Study of the Variability of Exceptional Kansas High School Seniors in Science and Other Academic Areas," Kenneth E. Anderson and Herbert A. Smith, University of Kansas, Lawrence, Kan. and Tate C. Page, Western Kentucky State College, Bowling Green, Ky.

3:30–3:50 "Changes in Teaching from Research in Science Education," Nathan S. Washton, Queens College, Flushing, N. Y.

3:50–4:10 "Needed Research in Science Education," Hubert Evans, Teachers College, Columbia University, N. Y.

4:10–4:45 Symposium: "How Can Research in the Teaching of Science Contribute to Other Agencies?" Thomas Reynolds, National Science Foundation, Washington, D. C., John R. Mayor, AAAS-Science Teaching Improvement Program, Washington, D. C., Herman Branson, Howard University, Washington, D. C.

4:45–5:00 Discussion

SUNDAY, FEBRUARY 17

BOARD ROOM

BUSINESS MEETING

A.M.

10:00–10:10 Report of Secretary-Treasurer—Clarence M. Pruitt

10:10–10:15 Report of Election of Officers

10:15–10:25 Report on Cooperative Committee —George G. Mallinson

10:25–10:45 Report of Liaison Committees; Advisory Committee to the U. S. Office of Education—Waldo W. E. Blanchet

10:45–10:55 Report of Educational Trends—Atomic Energy Committee, Abraham Raskin, Jerome Metzner, and William B. Reiner

10:55–11:00 Special Reports, Research in Science Teaching and Other Agencies—Nathan S. Washton

11:00 New Business

12:00 Lunch

OFFICIAL MINUTES OF THE THIRTIETH ANNUAL MEETING OF THE NATIONAL ASSOCIATION FOR RESEARCH IN SCIENCE TEACHING

HOTEL CLARIDGE, ATLANTIC CITY, NEW JERSEY

February 17, 1957

THE Thirtieth Annual Meeting of the National Association for Research in Science Teaching was called to order by President Waldo W. E. Blanchet. The official minutes of the Twenty-Ninth Annual Meeting held at the Hotel Sherman, Chicago, Illinois, April 23, 1956 were approved as published in the February, 1957, *Science Education*. Treasurer Clarence M. Pruitt made the annual Treasurer's report as published in this issue of *Science Education*. Dr. George G. Mallinson made the report for the Auditing Committee, consisting also of members James C. Adell and Ellis Haworth. The Treasurer's book was found to be correct and in balance. A motion was made by Boeck that the Auditing Committee report be accepted. The motion was seconded by Anderson. The motion carried.

Secretary Clarence M. Pruitt gave his annual report relating to the activities of the Association and its official journal, *Science Education.* The Secretary reported the passing of Ellis C. Persing of the Cleveland Public Schools on April 4, 1956. Mr. Persing was a charter and lifetime member of N.A.R.S.T. A motion was made by Oakes and seconded by Hubler that the Secretary convey to Mr. Persing's family the sympathy of the Association on the passing of Mr. Persing. The motion carried.

The Secretary reported the retirement from active teaching duties of Wilbur L. Beauchamp, Bertha M. Parker, Ira C. Davis, and W. R. Teeters, and that they were eligible for Honorary Life membership in N.A.R.S.T. A motion was made by MacCurdy and seconded by Herbert A. Smith that those named be given Honorary Life membership in N.A.R.S.T. The motion carried.

The Editor of *Science Education,* Clarence M. Pruitt, called attention to the new cover design for *Science Education.* The change relates to the use of a photograph on the front outside cover and an accompanying biographical sketch of an individual who has made a noted contribution to the improvement of science teaching. The Editor reported the reaction of both members of N.A.R.S.T. and readers of *Science Education* to be most favorable in general, and in many cases enthusiastic. (Reactions since then have been even more enthusiastic.)

The annual Cooperative report was made by the Cooperative Committee representative, Dr. George G. Mallinson. (The report is published in this issue of *Science Education.*) Miles made a motion, seconded by Metzner, that the Cooperative report be accepted. The motion carried.

The Educational Trends Committee report was made by Reiner for elementary education, by Metzner for secondary education, and by Raskin for college education. Obourn made a motion, seconded by Fraser, that the report be accepted. The motion carried.

A report was made to the Association of a tragic automobile accident to N.A.R.S.T. member Greta Oppe of Galveston, Texas. The Association voted to express to Miss Oppe its sympathy because of the tragic death of her sister and her own very serious personal injuries.

The Nominating Committee report was made by Chairman Donald G. Decker. Other members of the Committee were William C. Van Deventer and Mervin E. Oakes. The Nominating Committee presented the following slate of names for N.A.R.S.T. officers during 1957–58: President, Nathan S. Washton; Vice-President, Thomas P. Fraser; Secretary-Treasurer, Clarence M. Pruitt; Executive Committee, Waldo W. E. Blanchet, Vaden W. Miles.

Decker moved and Barnes seconded a motion that the Report of the Nominating Committee be accepted. Motion carried. It was then moved and seconded that the Secretary be empowered to cast a unanimous ballot for those named by the Nominating Committee. The motion carried.

A vote of appreciation was given to Clarence H. Boeck and his associate chairman Jacqueline Buck Mallinson, Clark Hubler, William Reiner, and Edward K. Weaver for the preparation of the splendid Fourth Annual Review of Research in Science Teaching published in the December 1956 issue of *Science Education.* It was announced that Dr. Ellsworth S. Obourn would serve as Chairman of the Fifth Annual Review Committee. Lillian H. Darnell will serve as Elementary Level Chairman, George T. Davis as Secondary Level Chairman, and Edward K. Weaver as College Level Chairman. There was considerable discussion relating to past Research Review reports and what should be the techniques used in preparing the Fifth Annual Report.

President Blanchet expressed his and the Executive Committee's appreciation for the

fine cooperation given by members in making this an unusually fine meeting. Many comments were made regarding the excellent program arranged by program chairman Washton. Attendance, papers, and discussions were unusually good. A vote of appreciation was extended by the N.A.R.S.T. members present to the members of the Executive Committee for its work during the preceding year.

President Washton next made a presentation of proposed activities for N.A.R.S.T. during the coming year. Important phases of this report related to the Fifth Annual Review and the republication of the now-out-of-print Curtis Digests published by the late P. Blakiston's Son and Company. It is also proposed that two or more additional volumes be published to bring the entire series up to date. Funds for financing this work are to be sought from the National Science Foundation. President Washton was authorized to proceed with contacting the National Science Foundation regarding the possibility of obtaining such funds.

It was also announced that contacts had been made with officials of the National Society for the Study of Education suggesting the preparation of a yearbook by members of N.A.R.S.T. This yearbook would follow and supplement the Thirty-First and Forty-Sixth Yearbooks previously published by the National Society for the Study of Education.

A motion was made and carried that the 1957 Annual Business meeting be declared adjourned.

Clarence M. Pruitt,
Secretary.

DINNER MEETING

Members of N.A.R.S.T. attending the annual dinner meeting were Gerald S. Craig, Nathan S. Washton, Waldo W. E. Blanchet, William C. Van Deventer, Kenneth E. Anderson, George G. Mallinson, Jacqueline Buck Mallinson, Thomas F. Fraser, J. Darrell Barnard, Ellsworth S. Obourn, Edward K. Weaver, George T. Davis, Lillian H. Darnell, Herbert A. Smith, Hubert F. Evans, James C. Adell, David A. Hilton, Abraham Raskin, Louis T. Cox, Jr., William D. Chamberlain, Clark Hubler, Henry Gould, Luther A. Arnold, Robert D. MacCurdy, Ellis Haworth, Nelson F. Beeler, Harold S. Spielman, Velma F. Huntley, Catherine Dale, Donald G. Decker, William Reiner, Martin L. Robertson, Ida Beth Schultz, Mervin E. Oakes, Vaden W. Miles, Cyrus W. Barnes, Clarence H. Boeck, and Clarence M. Pruitt.

FINANCIAL REPORT OF N.A.R.S.T.

February 17, 1957

RECEIPTS

Balance on hand	$ 00.00
Membership dues	1,257.00
Total	$1,257.00

EXPENDITURES

New York City A.A.A.S. meeting	$ 21.10
Atlantic City programs	37.50
Honorarium to Dr. Gerald S. Craig	25.00
Secretarial expense	51.40
Science Education	1,122.00
Total	$1,257.00
Balance on hand	$ 00.00

Clarence M. Pruitt,
Treasurer

A REPORT TO THE N.A.R.S.T. ON THE RELATIONSHIPS WITH THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE FOR THE YEAR 1956–7 *

George Greisen Mallinson
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INTRODUCTION

As with previous years the N.A.R.S.T. has continued with all the types of relationships with the A.A.A.S. that began before and during 1954–55. This report will deal therefore with three areas, namely, (a) Activities with the Cooperative Committee on the Teaching of Science and Mathematics of the A.A.A.S., (b) Participation at the Meetings of the A.A.A.S. Council, and (c) Symposium: Recent Research in Science Education, held at the One Hundred Twenty-Third Meeting of the A.A.A.S. in New York City on December 27, 1956.

ACTIVITIES WITH THE COOPERATIVE COMMITTEE ON THE TEACHING OF SCIENCE AND MATHEMATICS OF THE A.A.A.S.

Meeting of the Cooperative Committee

Since the last meeting of the N.A.R.S.T. the Cooperative Committee has met only on one occasion, namely in the A.A.A.S. Building, Washington, D. C., on October 11 and 13, 1956. The 1956 Spring meetings of the Cooperative Committee met prior to the Spring meeting of the N.A.R.S.T., while the 1957 Spring meeting of the Cooperative Committee follows this N.A.R.S.T. Meeting. Hence, this report deals only with one meeting. It may be noted also that the Cooperative Committee did not meet on October 12. The reason is that this Fall meeting was held during the dedication of the new quarters of the A.A.A.S., and the entire day of October 12 was left open for the participation of the members of the Cooperative Committee.

The cost of your representative's attendance at the Meeting was borne by sources other than the N.A.R.S.T. treasury.

Attendance at the Fall Meeting

Since a number of changes were made in the personnel of the Cooperative Committee during the year and several more are to be made shortly, it was decided to list only those attending the meeting together with their respective societal designations. A complete roster of the personnel of the Committee will be submitted in next year's report. Those in attendance at the opening of the meeting, as indicated by the secretary's minutes, follow:

Members Present:

- J. W. Buchta, American Institute of Physics, Chairman
- Henry H. Armsby, Engineers Joint Council
- Fred B. Dutton, Division of Chemical Education, American Chemical Society
- Alfred B. Garrett, Board of Directors, A.A.A.S.
- Phillip S. Jones, Mathematical Association of America
- George G. Mallinson, National Association for Research in Science Teaching
- John R. Mayor, Science Teaching Improvement Program, A.A.A.S.
- Brother G. Nicholas, National Association of Biology Teachers
- Fred H. Norris, Botanical Society of America
- W. E. Restemeyer, American Society for Engineering Education

*A report made by the N.A.R.S.T. Representative on the Cooperative Committee of the A.A.A.S. at the Thirtieth Annual Meeting of the National Association for Research in Science Teaching at the Hotel Claridge, Atlantic City, New Jersey, February 17, 1957.

Harvey Sorum, American Chemical Society
Henry W. Syer, National Council of Teachers of Mathematics
Wayne Taylor, A.A.A.S. Academy Conference
Bernard B. Watson, Secretary
Fletcher G. Watson, American Association of Physics Teachers
Harold E. Wise, Section Q (Education), A.A.A.S.
Dael Wolfle, Executive Officer, A.A.A.S.

Present by Invitation:
John A. Behnke, The Ronald Press Company
J. A. Campbell, National Science Foundation
Hilary J. Deason, High School Traveling Science Library Program, A.A.A.S.
George Sprugel, National Science Foundation, representing the American Society of Zoologists
I. E. Wallen, Science Teaching Improvement Program, A.A.A.S.

The new members attending their first meeting are Henry H. Armsby, representing the Engineers Joint Council, and Alfred B. Garrett, Ohio State University, who succeeded Harold K. Schilling as the representative of the Board of Directors of the A.A.A.S.

Activities of the Cooperative Committee

The first business dealt with a review of the past and present activities of the Committee. It was generally agreed that the Committee had contributed significantly, both directly and indirectly, to the advancement of science education during the past years. Some of the direct contributions had been Volume IV of the Steelman Report,[1] The UNESCO volume on laboratory apparatus,[2] and the development of the Science Teaching Improvement Program. Many indirect contributions have been effected by the members of the Committee through stimulation of activities in their respective societies.

The perennial problem involving the costs of representation for societies was discussed. It was noted that representatives of certain societies often failed to attend meetings of the Cooperative Committee because of the lack of funds. Hence, it was moved, seconded and passed "that the Committee reaffirm its policy that each member organization is expected to pay the travel expenses of its representative, and in the event that this is not possible, is urged to appoint a representative whose expenses will be borne by his institution or will be paid from other sources. The motion included a provision that this restatement of policy be called to the attention of all member organizations and particularly emphasized with respect to those organizations in connection with which this problem has been chronic."

A résumé was then made of the activities of the Science Teaching Improvement Program for the 1955–56 year. The résumé follows:

"1. *Colleges and Universities.* The work started in 1955–56 with scientists in colleges and universities will be continued. It is hoped that a plan can be developed for the promotion of this activity on a regional basis, for which leadership will be obtained from scientists working in their own regions. The plan calls for 18 regions, and we anticipate obtaining additional financial support so that each regional consultant would have an annual budget of approximately $300. A conference, or conferences, of all consultants would be held prior to the beginning of the program which probably now will not be before the second semester of this academic year.

"2. *Professional Education.* The cooperation with professional education groups will be extended to include further work with organizations on projects already started and new activities with other groups.

"a. *Joint Commission, A.A.C.T.A.-A.A.A.S.A.* proposal for financial support is to be considered

[1] Steelman, John R. (Chairman), *Manpower for Research: Volume Four of Science and Public Policy.* The President's Scientific Research Board, October 11, 1947. U. S. Government Printing Office, Washington 25, D. C.

[2] United Nations Educational, Scientific and Cultural Organization, *Inventories of Apparatus and Materials for Teaching Science,* Volumes I, II, and III.

by both Governing Boards this month. The new name of the Commission is Joint Commission on Education of Teachers of Science and Mathematics.

"b. *Certification.* Scientists will be invited to work with T.E.P.S. Commissions in the 48 states. A list of scientists in each of the 48 states was sent to T. M. Stinnett, Executive Secretary of the National Commission on Teacher Education and Professional Standards. Stinnett in turn sent these names to the appropriate states, with the request that the scientists listed be invited to participate in T.E.P.S. activities this year. A good response was received from the scientists, indicated their interest in the activity.

"c. *American Education Week.* Letters have been sent in cooperation with N.E.A. to state superintendents and secretaries of education associations, urging special attention to science education during American Education Week.

"3. Motivation and Guidance. A.A.A.S. Subcommittee on Recruitment and Guidance has recommended two projects. The project on films is now under consideration by two major universities. Preliminary steps have been taken to develop the community study.

"A.A.A.S. is cooperating with the N.A.S.-N.R.C. Educational Advisory Board in a review of the use of *Television* in science teaching. It is anticipated that the first step will be the preparation of a report on current activities in teaching science and mathematics by television. A surprising number of experiments in this area have been discovered. Cooperation in the preparation of the report will be given by representatives of the Joint Council on Educational Television, the National Science Foundation, the Committee on Educational Television of the American Council on Education, and the Office of Education.

"4. *Salaries.* S.T.I.P. is planning to cooperate with N.E.A. on a special study of merit salary increases. The Department of Classroom Teachers is holding a conference on merit salary increases in the two days following Thanksgiving. Interest in this topic has also been indicated by a number of other departments of N.E.A.

"5. *Working Conditions.* A possible study of working conditions for teachers in connection with the Arlington County project may be developed. An interesting proposal has been received from Ventura County, California. The proposal from California covers purchase of equipment and library materials which will be used in projects involving science teachers in research.

"6. *Science Counselors.* The counselor study is under way in four centers. See brochure.

"7. *Awards.* There is new hope for financial support. If this materializes, the awards will be much better financially than originally planned. It is now obvious that the teacher award program cannot be inaugurated for this academic year. We feel confident, however, that the first awards can be given at the A.A.A.S. meeting in 1957.

"8. *Conference on Mathematics Instruction.* The Conference was held in Washington on October 1 and 2, under a special grant from the Carnegie Corporation of New York. A detailed report will be available later this month.

"9. *Corresponding Study.* A special committee has been appointed by N.U.E.A. to study existing courses in science and mathematics, and plan new ones. Dr. Wallen will meet with the N.U.E.A. committee in November to develop plans for a complete listing of existing courses and a method of determining areas in which there is need for new courses. It is hoped that the new courses might be offered on a cooperative basis by a rather large number of universities.

"10. *Questionnaires.* Much work has been done on questionnaires to be addressed to state departments of public instruction, school administrators, and teachers. This project is in cooperation with the Office of Education, N.S.T.A., N.S.F., and other interested agencies, including the President's Committee for the Development of Scientists and Engineers.

"11. *Women's Colleges.* The Association of Southern Women's Colleges will make preliminary plans with S.T.I.P. at their annual meeting in Dallas in December. There is indication that many of the best-known women's colleges are now giving special attention to teacher education programs. In a number of instances these have been developed as a fifth year of study in cooperation with a neighboring university.

"12. *State Colleges.* Plans are under way for special regional conferences of state colleges in the Midwest, to consider ways of improving science and mathematics teacher education programs and relationships with secondary schools. A committee has been appointed to draw up a proposal for the midwest conference, probably to be held in Chicago in January 1957. The eight midwestern states closest to Chicago include 43 state colleges. Under the proposal each of these colleges would be asked to name a representative from science and one from mathematics.

"13. *Arlington County Project.* Special study groups of teachers are planned for this year. See reference in item 5. Preliminary steps have been taken to continue the type of summer program offered in 1956. Reports of the eight cooperating colleges and universities on enrollments in the summer of 1956 are very encouraging.

"14. *Essay Contest.* Announcements have been made of the Mathematics Teaching Essay Contest in cooperation with Kappa Mu Epsilon. Essays are due April 1, 1957. The essay contest project will cost S.T.I.P. only $50. Similar offers were made to appropriate groups in biology, chemistry, and physics, but to date there has appeared to be no interest in this in the other sciences.

"15. *Junior Science Activities.* Support has been given to the development and improvement of Junior Academies, Science Fairs, and Science Clubs. Plans are under way for a conference of representatives of Junior Academies. Special

attention will be given to Junior Academies at the A.A.A.S. meeting in December.

"16. *Science Legislation.* A summary of science education legislation introduced in the last session of Congress was distributed at the A.A.A.S. Co-operative Committee meeting."

Your representative at this time would like to make a personal observation about the functioning of S.T.I.P. As he stated at last year's convention of the N.A.R.S.T., he believed that there were two major flaws:

1. The size of the original monetary grant from the Carnegie Corporation was not sufficiently great to warrant such a wide diversity of activities for a three-year period. He seemed to believe that too many activities were being touched superficially. Hence the contacts made by S.T.I.P. with other societies and organizations were much too fleeting to have any effect whatsoever. There is much evidence to support the validity of this statement.
2. Much of the effort of S.T.I.P. was being devoted to activities and meetings sponsored jointly with the large universities. While such institutions make tremendous contributions to science and technology, the majority of science teachers are trained in the smaller colleges. Your representative was of the opinion that more time and effort needed to be spent with these smaller institutions.

Recently, there seems to be a trend toward channelling efforts into fewer activities and devoting more time with the smaller schools. The extent to which this trend will continue, or have influence, is still a matter of conjecture.

A number of sub-committee reports were then made, the details of which may be read in the minutes distributed at the N.A.R.S.T. meeting, or obtained from your representative.

National Science Foundation Activities

Dr. J. A. Campbell, Program Director of the N.S.F. described the science education programs of the N.S.F. for the immediate future. They include the following:

1. About 85 summer institutions for 1957.
2. About 16 year-long institutes for 1957–58 which will provide for 800 teachers.
3. In-service training: Afternoon and evening science-content courses. Two such institutes will be established on an experimental basis.
4. Visiting scientist program—college level.
5. High-school science demonstrator program: Demonstrators were trained at Oak Ridge during the summer.
6. Traveling library program, A.A.A.S.-N.S.F.
7. Biosciences Division, N.S.F., has a program for granting stipends to enable individuals to do summer work at biological experiment stations. High-school and college teachers, and college undergraduates are eligible.
8. N.S.F. has received a proposal for a conference of elementary-school science supervisors, as well as proposals for films and television programs in science teaching.

High School Traveling Science Library Program of the A.A.A.S.

Dr. Hilary J. Deason reported on the Traveling Library Program administered by the A.A.A.S. under a grant from the N.S.F. The number of schools participating in the program is being increased this year and, at the same time, the number of books being sent to each school has risen from 150 to 200. Books, which are sent to each school in groups of 50, will be allowed to remain in the school for a period of two months instead of one month as permitted last year.

Your representative has had the opportunity to make use of these science libraries in a number of workshops designed for teachers of science at both the elementary and secondary levels. While he has made no objective or detailed evaluation of the effectiveness of these libraries, there was general agreement that the A.A.A.S. had contributed a fine service to the high schools. Your representative hopes that the A.A.A.S. will study thoroughly the values that may have accrued through the use of these libraries, and publish the results for the use of those who are interested in motivating young people to read scientific literature.[1]

Miscellany

A number of proposals for sub-committee action were made and a number

[1] A description of these libraries may be found in: George Greisen Mallinson, "A Report to the N.A.R.S.T. on the Relationships with the American Association for the Advancement of Science for the Year 1955–56," *Science Education,* XLI February, 1957, 70–78.

of sub-committees were appointed. However there were few activities of major import other than those described earlier. In general, your representative seemed to believe that the activities of the Cooperative Committee at this meeting generally involved reports of projects already underway, rather than the development of new ones. This, no doubt, was a result of one full day of activity at the dedication of the new A.A.A.S. building. The program at this dedication dealt with nuclear energy and was of exceptional quality. Much of the program is reported in the January 1957 issue of *Scientific Monthly*.

PARTICIPATION AT THE MEETINGS OF THE A.A.A.S. COUNCIL

The N.A.R.S.T. by virtue of being an affiliate of the A.A.A.S. has a voice in the meetings of the A.A.A.S. Council. Many activities and discussions took place at the Council meetings in New York City on December 27 and 30, 1956, only those activities of significant interest to the N.A.R.S.T. are reported here, however.

1. It was decided that the "Associate" status of societies with the A.A.A.S. be dropped and that all cooperating groups become "Affiliates." In general, this means that all cooperating groups would be expected to take a full share of responsibility or the functioning of the A.A.A.S., rather than merely participating at meetings. Your representative approves of this wholeheartedly. Those groups now considered "associates" will be offered the status of "affiliates." The N.A.R.S.T. has, of course, been an affiliate since 1954.

2. There was a suggestion from certain quarters to assess each affiliate $25.00 per year to defray partially the cost of the attendance of the members of the A.A.A.S. Council at the annual meeting. Your representative voted against such an assessment, as did the majority of the Council members. The vast differential of wealth and numbers of members of the various affiliates made such an assessment, in the opinion of your representative, seem inequitable.

A number of other actions chiefly of significance to the A.A.A.S. were, of course, taken. N.A.R.S.T. members will find reports of such actions in the February 1957 and ensuing issues of *Scientific Monthly*.

SYMPOSIUM: RECENT RESEARCH IN SCIENCE EDUCATION HELD AT THE ONE HUNDRED TWENTY-THIRD MEETING OF THE A.A.A.S. IN NEW YORK CITY IN DECEMBER 1956

At both the Berkeley, California Convention in 1954, and the Atlanta, Georgia Convention in 1955, symposia similar to the one described in the heading were held and were tremendously successful. Consequently, the N.A.R.S.T. decided to cooperate on such a venture at the New York City Convention. The program for the meeting was as follows:

THURSDAY MORNING, DECEMBER 27

9:00 A.M. East Room, Hotel Sheraton-McAlpin; *Symposium: Recent Research in Science Education.* Arranged by Nathan S. Washton, Queens College, New York, N. Y.

NATHAN S. WASHTON, *Presiding*

1. "Survey of Research in Elementary School Science Education," George G. Mallinson, Western Michigan College, Kalamazoo.
2. "Implications of Research in Elementary School Science Education," Harry Milgrom, Supervisor of Science and School Gardens, New York City Elementary Schools.
3. "Survey of Research in Secondary School Science Education," William B. Reiner, Board of Education, Bureau of Educational Research, New York City.
4. "Implications of Research in Secondary School Science Education," Jerome Metzner, Bronx High School of Science, New York City.
5. "Survey of Research in College Level General Education Science," Edward K. Weaver, Atlanta University.
6. "Implications of Research in College Level General Education Science," Abraham Raskin, Hunter College.

The symposium was exceptionally well attended. The room, with chairs provided originally for 120 persons was quickly filled and many more chairs had to be provided. It must be re-emphasized that these symposia have always been scheduled in

cooperation with the others of the Joint Science Teaching Societies affiliated with the A.A.A.S., namely, the A.N.S.S., N.A.B.T. and N.S.T.A. They have not been enterprises purely of the N.A.R.S.T.

At the Indianapolis Convention in 1957

At present your representative, together with Dr. Washton and representatives from other societies, is studying various aspects of cooperation at the next meeting of the A.A.A.S. in Indianapolis in December 1957. The N.A.R.S.T. will again take the initiative for suggesting and developing a symposium, in cooperation with the others of the Joint Science Teaching Societies, similar to the ones just described. Past successes seem to suggest that such a step is defensible.

SUMMARY

Your representative is firmly convinced that the cooperation and activities of the various societies described in this report are absolutely essential if the needs of science and technology in the next years are to be met. He also urges that all members of the N.A.R.S.T. give full support to those activities that are helping the field of science teaching to step forward.

THE PSYCHOLOGY AND PHILOSOPHY OF SCIENCE TEACHING *

GEORGE GREISEN MALLINSON
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SEVERAL months ago Dr. Blanchet suggested to me that it might be desirable at the next meeting of the N.A.R.S.T. to examine the philosophy of science teaching presented in the Thirty-First [1] and Forty-Sixth [2] Yearbooks of the N.S.S.E., and to evaluate the Yearbooks themselves in terms of recent thinking in the field of science teaching, and in light of recent studies in the psychology of learning. Such is indeed a large order since both Yearbooks have provided a sound basis for science teaching since their appearances. However, the proposal was an intriguing one and it was accepted.

It is well-known among science educators that these two documents have articulated the objectives of science teaching more effectively than any other publications. Yet, from time to time, some looks of askance have been cast on them. The speaker would like to postulate two reasons for this:

1. The Yearbooks are written in pedagogical terms that are not easily understood by the fledgling and, indeed in many cases, by experienced science teacher.
2. The Yearbooks emphasized *what* should be done in the field of science teaching without giving a clear indication of *how*. Further, neither of them seemed to place sufficient emphasis on modern Gestalt psychology of learning or on the perceptual process.

Neither of these points are of course mutually exclusive. Hence, no effort will be made to discuss them absolutely separately. Rather, the comments that follow will serve probably to amplify both points.

Both Yearbooks, in general, postulated certain basic objectives for science teaching, namely, functional information, functional concepts, functional understanding

* Paper presented at the Twenty-Ninth Annual Meeting of the National Association for Research in Science Teaching, Hotel Sherman, Chicago, Illinois, April 21, 1956.

[1] *A Program for Teaching Science.* Thirty-First Yearbook of the National Society for the Study of Education, Part 1. Chicago: Distributed by the University of Chicago Press, 1932. Pp. xii + 364.

[2] *Science Education in American Schools.* Forty-Sixth Yearbook of the National Society for the Study of Education, Part I. Chicago: Distributed by the University of Chicago Press, 1947. Pp. xii + 306.

of principles, instrumental skills, problem-solving skills, attitudes, appreciations, and interests. These, of course, are amplified and illustrated in the Yearbooks with examples such as "Problem-solving skills—sense a problem, define a problem, test the hypothesis by experimental or other means"; "Functional understanding of principles—energy can be charged from one form to another; all matter is composed of single elements or combinations of elements"; "Attitudes—intellectual honesty—scientific integrity, unwillingness to compromise with truth as known"; and "Appreciations—sensitivity to possible uses and applications of science in personal relationships and disposition to use scientific knowledge and abilities in such relations (attitude)."

It would be difficult indeed to find a science educator who would disagree with these statements. Yet it is the experience of the author that most of them are meaningless phrases to the teacher in the field. Few seem to understand the implications of these statements in the day-to-day teaching process. They seem to find it impossible to translate them into classroom activity. While it must be emphasized that these objectives are eminently meritorious, they have not, however, been articulated in "the words of one syllable" so as to be easily understood by the classroom teacher.

Even among trained science educators, the term "functional" has a vast number of connotations depending on who attempts to define it and the context in which it is used. The term "attitudes" seems to refer more or less to moralism rather than to perceptual patterns that govern behavior. The term "scientific method" indeed by many scientists is denied existence in so far as precise meaning is concerned. In other words, to many teachers, the objectives as listed represent verbalizations that need further clarification.

The matter has further been confused by the use of the word "doing." In efforts to clarify the objectives indicated in the Yearbooks, some science educators have suggested that the Yearbooks should have emphasized that students should "do science" rather than "read about it." A rash of efforts followed to identify "doing activities" that might help attain the objectives. Many of the activities thus identified kept the student busy but failed to teach him very much. Actually, the word "doing" should have been given an entirely different connotation. Just as mathematical experiences teach a child to add, subtract, multiply, divide and estimate more efficiently, so science experiences should train a student to *do* something better. Hence, the term "doing" refers not to activities that keep a student busy, but rather to skills he should have attained as a result of the activities. The Yearbooks, therefore, in a measure failed to identify what a child should do better in words that a classroom teacher could understand. They did point out for the first time in an organized way that subject matter and science activities are means to an end and for that they have proved their worth. However, had the objectives been articulated in *doing* as connoted above, their influence would have been much more wide-spread.

The second point mentioned deals with "what" rather than "how." The writer believes definitely that while the objectives listed in the Yearbooks are given sufficient treatment, the ways for implementing them are not. Perhaps had the "doing" connotation been emphasized as indicated above, this criticism could not be made. There is much evidence to support this point if one examines some of the research stimulated by the Yearbooks. In the wake of their appearance, came a rash of studies that sought to identify the various principles of biological and physical science of value for inclusion in science courses at all levels. These principles have been re-evaluated and refined by other investigators in an effort to "grade place" them. Other investigators sought to develop lists

of topics, experiments, demonstrations and audio-visual aids that might contribute to understanding of the principles.

Unfortunately, a close scrutiny of these studies would indicate that many degenerated into little more than "a chess game" of placing, allocating, and shifting statements of principles, topics, and attitudes. It seems that they give little emphasis to the fact that the statements of the objectives are merely *verbalizations of what goes on inside the science student.* One can readily get the impression from reading them that most of the effort has been given chiefly to identifying areas, concepts, and principles to be covered, rather than attention to the means by which experiences in these areas could be used to train a student to function scientifically.

Lastly, it seems that the Yearbooks have failed to take sufficient cognizance of the modern discoveries in the field of learning, especially in the areas of Gestalt psychology and perception. True, they did point out that the human mind is not a muscle that is developed through exercise, and they did indicate that it is *not* a space to be filled with knowledge as a hole is filled with water. However, they did not make clear what the human mind really is, nor clearly describe the dynamics of its functioning. They failed to point out that the mind is a name designating an organizing function rather than a structure. In general, superficial descriptions were made of the characteristics of situations that enhance learning, and of certain intellectual designs that appear in the consciousness of the student as a result of participation in these learning activities.

Actually, the mind is a dynamic mechanism that organizes the various experiences it receives into meaningful patterns. The patterns are constantly being resynthesized with the new experiences the mind receives. However, the patterns are not merely understandings, appreciations, attitudes, or knowledges. They represent active forces that cause individuals to react to the new experiences and situations that they face. The types of patterns that are organized depend on *how* experiences are presented and how meaningful and motivating they are, far more on *what* they are. Hence, the Yearbooks may have been amiss in not emphasizing *how* experiences should be presented so that they could be perceived and organized into the behavioral or "doing" influences that represent the true meaning of science learning.

This may seem to be a condemnation of the efforts of the scholars who prepared these Yearbooks. It is not! Those men did not have on hand the findings of modern psychology. If, today, another group of science educators were to produce a sequel to these Yearbooks, it is doubtful whether they, either, would take real cognizance of the modern psychology of learning and its implications for science teaching. Many of our present-day science educators are not sufficiently schooled in modern psychology to produce the "up-to-date" document.

The Yearbooks represented the best up-to-date thinking of their day as did the steam locomotive. The fact that the Diesel replaced the steam locomotive is not a condemnation of the latter, but an indication that "times change." The Yearbooks needed to be superseded by one emphasizing the modern psychology of learning as it relates to the development of perceptual and behavioral patterns. It can be done. But, it won't be done by examining superficial characteristics, descriptions, and symptoms of learning behavior and prescribing "aspirin." It will be done successfully only by those who have studied deeply various phases of behavior dynamics and who understand the perceptual process.

Those who are schooled in these areas and also are trained in the functions of science teaching can produce a Yearbook which will be a noble follower of the Thirty-First and Forty-Sixth.

A COMPARISON OF THE KNOWLEDGES OF PHYSICAL SCIENCE WITH THOSE OF BIOLOGICAL SCIENCE OF COLLEGE STUDENTS *

GEORGE GREISEN MALLINSON
Western Michigan University, Kalamazoo, Michigan

AND

CONWAY C. SAMS
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THE PROBLEM

DURING the past several years nearly all colleges have been developing programs of basic studies or general education. The programs vary a great deal from one institution to another. In general, however, students are expected to complete a number of basic courses in communications, humanities, social science, and natural science as a degree requirement. In some schools specific courses are required, in others students may elect from a variety of courses in certain areas in order to satisfy the general-education requirements. This latter type of program has caused a number of problems. In many schools certain options have proved to be much more popular than others. Many reasons can, of course, be postulated. However, the general-education program is designed basically to broaden individuals especially in those areas in which their backgrounds are weak. Observations of actual practice do not suggest that this happens. It seems to be especially true in the field of science where according to the experiences of educators, the vast proportion of students elect their general-education science courses in the biological rather than in the physical science area. Yet the evidence available does not seem to suggest that students are so well versed in the physical sciences as to warrant such a trend.

As a result it was decided to investigate this situation as well as a number of corollary questions that presented themselves.

The purpose of this study is, therefore, twofold: (1) to compare the competencies of different groups of college students in certain aspects of the biological and physical sciences; and (2) to compare the competencies of males with those of females in these areas.

METHODS EMPLOYED

During the school years 1950–54, and prior to the establishment of the program of basic studies, the first author taught general psychology to many groups of students at Western Michigan University. The students entering his classes were without doubt representative of the college population. Over half the students during those years elected general psychology and their enrollment in the various sections was randomized. Every possible variety of student could be found in each of the sections.

The first author administered to his students during this period the Minnesota State Board Examination in Biology (1947) and the Minnesota State Board Examination in Chemistry (1947). Both of these tests were designed to measure the attainment of the major objectives of the teaching of science (as indicated in the Forty-Sixth Yearbook of the National Society for the Study of Education[1]) by students who had completed a year's study in each of the respective subjects in high school. Further, there were extensive data

* Paper presented at the Twenty-Ninth Annual Meeting of the National Association for Research in Science Teaching, Hotel Sherman, Chicago, Illinois, April 21, 1956.

[1] "*Science Education in American Schools,*" *Forty-Sixth Yearbook of the National Society for the Study of Education, Part I.* Chicago: Distributed by the University of Chicago Press, 1947. Pp. 19–40.

TABLE I

RELIABILITIES AND VALIDITIES OF TESTS FOR BIOLOGY AND CHEMISTRY *

Test	Coefficients of Reliability	Coefficients of Validity
Biology	.91	.51, .53, .62, .79, .87
Chemistry	.92	.64, .68, .68, .87, .89

* All coefficients of correlation are significant at the 1 per cent level.

concerning the reliabilities and validities of these tests.[2]

The coefficients of reliability of the tests were computed by Anderson using Hoyt's Method. The coefficients of validity were computed by comparing the scores made by students on the science tests with teachers' estimates of their final grades in these areas of science and with scores the students obtained on both the Cooperative Biology Test and the science sections of the Iowa Tests of Educational Development. Table I lists the results of the computations for these tests.

It must be pointed out here that the authors do not suggest that the test in chemistry measures achievement in all the fields of physical science. However, no test in physics or earth science comparable with those described above was available. Hence, it was decided to use these two tests alone, recognizing that the conclusions would have to be confined to the chemical aspect of physical science.

The first computation involved comparisons of boys with girls on the biology test and among various classes. The classes here refer to groups of students who participated in the experiment during different semesters. The analysis of variance technique described by Kenney[3] was used in making all the computations.

Table II contains these computations.

Table III contains the same computations as Table II, but for the chemistry test.

The next computation was designed to compare the differences between the scores the students obtained on both tests. The difference method used in this computation was satisfactory without normalizing the scores since it was possible to get the "within" unbiased estimate of individual variances of differences and the individual variances are so nearly equal (142.68 and 142.17).

Table IV contains these computations:

[2] Kenneth E. Anderson, "The Relative Achievements of the Objectives of Secondary School Science in a Representative Sampling of Fifty-Six Minnesota Schools." Unpublished doctor's dissertation, University of Minnesota, 1949. Pp. 62–5.

[3] John Francis Kenney, *Mathematics of Statistics: Volume 2.* New York: D. Van Nostrand Co., Inc., 1947. Pp. 265 ff.

TABLE II

COMPUTATIONS FOR THE BIOLOGY TEST

Sex	Class I	II	III	IV	V	Totals	Means
Boys n	119	112	113	83	79	506	54.901
Σx	6981	6042	6045	4523	4189	27780	
Girls n	81	87	62	55	56	341	54.011
Σx	4752	4779	3267	2895	2725	18418	
Totals n	200	199	175	138	135	847	54.543
Σx	11733	10821	9312	7418	6914	46198	
Means	58.665	54.376	53.211	53.753	51.214		

Analysis of Variance

Category	Sum of squares	df	mean square	F	$F_{1\%}$	
Sexes	287.026	1	287.026	2.009	6.7	
Classes	5550.922	4	1387.730	9.726	3.4	Significant
Interaction	642.576	4	160.644	1.126	3.4	
Individuals	119423.815	837	142.681			

TABLE III

COMPUTATIONS FOR THE CHEMISTRY TEST

Sex	Class I	II	III	IV	V	Totals	Means
Boys n	119	112	113	83	79	506	39.016
Σ x	4557	4369	4663	3072	3081	19742	
Girls n	81	87	62	55	56	341	33.079
Σ x	2644	3077	2243	1619	1697	11280	
Totals n	200	199	175	138	135	847	36.626
Σ x	7201	7446	6906	4691	4778	31022	
Means	36.005	37.417	39.462	33.993	35.393		

Analysis of Variance

Category	Sum of squares	df	mean square	F	$F_{1\%}$	
Sexes	5069.585	1	5069.585	35.658	6.7	Significant
Classes	3021.184	4	755.296	5.312	3.4	Significant
Interaction	307.094	4	76.773	0.540	3.4	
Individuals	118997.977	837	142.172			

TABLE IV

COMPUTATIONS FOR DIFFERENCES IN SCORES ON BIOLOGY AND CHEMISTRY TESTS

Class		Boys	Girls	Totals
I	n	119	81	200
	Σ x	2424	2108	4532
II	n	112	87	199
	Σ x	1673	1702	3375
III	n	113	62	175
	Σ x	1382	1024	2406
IV	n	83	55	138
	Σ x	1455	1276	2731
V	n	79	56	135
	Σ x	1108	1028	2126
Totals	n	506	341	847
	Σ x	8042	7138	15180

Analysis of Variance

Category	Sum of squares	df	mean square	F	$F_{1\%}$	
Totals	95352.038	546				
"Within"	81550.614	837	97.432			
Sub total	13801.424	9				
Sex	4886.977	1	4886.977	50.16	6.7	Significant
Class	8442.852	4	2110.715	21.66	3.4	Significant
"Interaction"	241.608	4	60.402	0.619	3.4	

CONCLUSIONS

In so far as the techniques used in this study may be valid, the following conclusions seem defensible:

1. There doesn't seem to be much difference between the males and females who participated in this study in so far as biological knowledge is concerned.

2. The boys seem to perform significantly better than the girls on the chemistry test. This may be due to the fact that boys ordinarily elect chemistry more frequently than girls.

3. The groups were extremely diverse with respect to their achievements. This factor seems to have almost as much effect on relative scores on the two tests as the sex factor. This is surprising in that such

differences do not ordinarily appear when the personnel of the groups are randomized from school populations that are similar.

4. The students perform significantly better in the area of biology than in chemistry whether the sex or class structuring is considered. Table IV indicates that there is a marked difference in favor of biology.

5. It would seem, if the students are expected to broaden their cultural backgrounds from the program of basic studies, that more of them should elect the course in physical science. This of course must be considered in the light of the fact that the scores on the chemistry test are the only bases here used for measuring knowledges of physical science.

IS SURVIVAL DEPENDENT ON IMPROVED SCIENCE EDUCATION?

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INTRODUCTION

As interested and biased students in perpetual study of nature we have become aware of the evolution of lifes simpler forms to more complex ones. It appears that the simpler free and independent forms combine forces to merge their powers into a higher more complex unit. In our age of antibiotics, atom energy, and supersonic speed we have retained many barbarian social customs, modes, morals and behavior. We as a nation and a people have immediate and urgent need to increase our survival potential and depart from the savage barbarisms of our social behavior or we as a people will join the Incas, Aztecs and Manchus.

The readers of our papers and periodicals can hardly escape the flow of articles recently about the critical shortage of scientists and engineers and what it will mean for our nation [12]. Studies have shown that interest in science is acquired at an early age [15, 16] and the choice of vocation occurs during the early school experiences of most students [10]. It would seem that our science departments need to be revised and reorganized to be able to meet our new and critical needs for creative scientists and engineers and an understanding and sympathetic science consuming citizenry.

HISTORICAL REVIEW

The objectives of science teaching in America are not only to impart factual information, but according to Henry [7] there exists other objectives including acquisition of instrumental skills; the development of problem solving skills useful throughout life; the establishment of a scientific attitude in the students mind; the appreciation of the area of science in a young citizen; finally the kindling of interests in science in the developing adult. To accomplish these objectives various plans have been suggested. A few such plans and suggestions include those of Anibal and Leighton [1], Hurd [11], Hill [8], Hodge [9], Rodean [13], Todd [14], and the Thirty-First Yearbook [2]. They have various points of accentuation and omission. Collectively, however, they may be summarized by a recommendation for a continuous science program from kindergarten through grade twelve [2], integrated courses in the high school [9], covering major principals [11], of a practical nature [14], avoiding overlapping [13], meeting the needs of everyday life [11] and related to people's interests [8]. Heiss, Obourn and Hoffman [6] suggested how science clubs, trips and journeys, multisensory aids, and free materials may be used to achieve these objec-

tives. The functions of laboratory work and teacher demonstration is shown in the Thirty-First Yearbook [2]. A review of a large body of literature failed to uncover any reports on how the head of a science department could operate his department and offer courses so designed and so presented that these objectives can be achieved.

HYPOTHESIS

If we can experience better methods of teaching and administering science and can be shown that we can master them we will want to imitate and improve on them.

OBSERVATIONS

1. Over a period of several years, we have made a careful observation of a wide variety of scientific organizations and installations. These include the following: Elementary schools, Junior High School, Colleges, Universities, Science Fairs, Science Congresses, Science Workshops, Clubs, Seminars, Conventions, Scientific Supply Houses, Scientific Industries, Laboratories, Hospitals, Zoos, Aquariums, Reservations, Experiment Stations, Libraries, and Museums.
2. Have joined and actively participated in a wide variety and number of scientific and professional organizations.
3. Have taught science courses to people from the age of six to sixty by many methods.
4. Have corresponded with science editors, teachers, researchers, and professors and students.
5. Have read a multitude of books on education and on science.
6. Have observed and used films, strips, slides, and other multisensory aids.
7. Discovered that we had learned a multitude of methods, techniques and devices to use in teaching science. We found that there were immense stores of teaching materials available in a tremendous variety of places. Most of these are obtainable by almost anybody.
8. Have acquired a library of reference books and reports on all areas of science education.
9. Have tried in "action research" many promising ideas.

DISCUSSION

What we have done has been a learning experience. What we have learned we have recorded and retained. In most instances we have tried to utilize these ideas. We have even improved on some. This has been no unique experience nor a difficult one to obtain. What we have done others can do and have done. Therefore, there is a vital need to pool and share our common experiences so that we all can experience more and be the wiser. It occurs to me, the writer, that it may be possible to apply the techniques of democracy [5] and recognizing the importance of the human ego [4] utilize the natural method of problem solving [3] to the solution of this large and complex task. Application of these important factors to the solution of this task could be made if periodic workshops or meetings (organized on a democratic basis [5] and stressing each individual's essential importance [4] dedicated to maintaining a friendly, sociable atmosphere) were to be carefully organized and operated. The members of this workshop would be invited to participate in a study by individual or group investigation and a group pooling and sharing of the solutions in reports delivered to the group about the problems [3] that follow:

SOME SUGGESTED PROBLEMS FOR WORKSHOP INVESTIGATION

1. Is our community a source of materials to study?
2. What are the local needs for employment of our graduates?
3. Are industry sponsored aids good for us?
4. Is interdepartmental course integration desirable?
5. Is intradepartmental course integration desirable?

6. Would the student's analysis of our course be valuable?

7. What are the uses of complete advance schedules in courses?

8. Are bulletins a trial or a triumph?

9. Would a departmental science fair be worth while?

10. Can a better marking system for science be developed?

11. What are the goals for American Education today?

12. What are the goals for Science Education today?

13. Should we try to organize a science congress?

14. Can we do a follow-up study of our pupils?

15. Would an analysis of our students be useful?

16. Educational growth, do we get it?

17. Are classroom reference book libraries useful?

18. What new courses do we need to offer?

19. What modernizing do we need in our courses?

20. What rental films are available to us?

21. How can we get the best use of films in science?

22. What film strips and slides are available?

23. What free films are available to us?

24. What fairs, contests, and scholarships are available to our students and ourselves?

25. What periodical do we need to take?

26. What local field trips do we need to take?

27. Can we get some visiting experts to demonstrate?

28. What other science clubs do we need?

29. What scientific equipment do we all have?

30. Can we all use each other's equipment to advantage?

31. Can we operate on teachers' budgets within the department budget?

32. Can we exchange our surplus science books?

33. What transcriptions are available for our use?

34. Can we build better units for our courses?

35. What long range plans should we have for equipment, supplies, books, courses, curriculum?

36. How good are our teaching methods?

37. The double lab period, can we abolish it?

38. Can we use more intern teachers? What about lab assistants?

39. How can we increase extra curricula activities?

40. How can we assist each other in teaching?

41. How can the Head be of more assistance to his colleagues in the department?

42. Are we wasting time by duplicating each other?

43. How can we make our courses less academic and more functional and lifelike?

44. How can we capture the interest of our students?

45. What other problems should this body discuss and try to solve?

SUMMARY AND CONCLUSIONS

The problem of the organization and administration of a science curriculum so as to obtain vertical and horizontal integration is essentially one of human relationships, the democratic way of life, fundamental principles of human learning and pooling and sharing of known good solutions to the many problems of science education. If the members of a science department are organized into a workshop in which good human relationships are obtained, if they pool and share their experiences, if they individually or in a group investigate their mutual problems and report the solutions to the group, most of the problems inherent to the organization and administration of a science curriculum will be solved.

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THE SELECTION OF EXPERIENCES IN PHYSICAL SCIENCE FOR ELEMENTARY EDUCATION MAJORS *

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STATEMENT OF THE PROBLEM

The purpose of this investigation was to determine criteria for the selection of laboratory experiences suitable for an integrated course in physical science designed for the education of elementary school teachers.

DEFINITIONS

Physical Science. That body of knowledge included in the fields of physics, chemistry, astronomy, meteorology, and geology.

Integrated Physical Science Course. A course of study in which the items of knowledge of physical science are taught and learned not as isolated bits seemingly unrelated to each other, but as unified wholes, i.e., without classifying them into the traditional fields mentioned above, but relating them naturally to the life and environment of the individual and society.

Laboratory Experiences. Those activities engaged in by the student in that portion of the science course in which apparatus or materials are manipulated for observation by only the performer or performers in an attempt to solve a problem in science.

Presentation. That part of a laboratory experience which includes the title and the directions and instructions—verbal, pic-

* Paper presented at the Twenty-Ninth Annual Meeting of the National Association for Research in Science Teaching at Hotel Sherman, Chicago, Illinois, April 22, 1956. Based on the author's Doctoral study for the degree of Doctor of Philosophy in the School of Education, New York University. Thesis accepted April 1954 under the title: *A Determination of Criteria for Selection of Laboratory Experiences Suitable for an Integrated Course in Physical Science Designed for the Education of Elementary School Teachers.*

torial, and diagrammatic—and questions which lead the student to the conclusions to be derived from the experience.

Elementary School. That portion of the American school system including the kindergarten and grades one through six.

BASIC ASSUMPTIONS OR PHILOSOPHY

1. The study of physical science is (or should be) an essential element in the education of the individual at all levels in the school program, for the purpose of helping him acquire a functional understanding of the physical world about him the interrelations among the elements of that world, the laws of movement (change) of that world, and the reciprocal relations between that world and the society of which he is a part.

2. An integrated physical science course is a better vehicle for the training of elementary school teachers than the traditional college courses in physics and chemistry.

3. Laboratory experiences are an essential element in the science training of elementary school teachers.

4. The majority of the students taking this integrated physical science course are not primarily interested in the field of science as a professional objective.

BACKGROUND OF THE STUDY

At the time this study was started the investigator had for four years taught a physical science course in the State Teachers College at Salisbury, Maryland, which trains elementary school teachers. The course was separated into physics one semester and chemistry the other. High school laboratory manuals were used in each section of the course. There was a need for an integrated physical science course. The establishment of such a course awaited only the building of a suitable set of laboratory experiences, designed to develop in the students those skills, concepts, interests, and attitudes, and that knowledge of the principles of physical science which would enable them later to engage in and supervise activities in the science education of elementary school children. The laboratory experiences, when developed, were made the heart of the course.

METHOD

1st phase. Formulation of a list of objectives of laboratory experiences in an integrated physical science course designed for the education of elementary school teachers from the objectives of science education as expressed in certain publications of science educators.

The sources of the objectives were: the Thirty-first[1] and the Forty-sixth[2] Yearbooks of the N.S.S.E., the Progressive Education Association committee report *Science in General Education,*[3] and the American Council of Science Teachers pamphlet *Science Teaching for Better Living.*[4] From the Forty-sixth Yearbook[5] were taken the eight general types of objectives of science in general education: information or facts, concepts, principles, instrumental skills, problem solving skills, attitudes, appreciations, and interests. These formed the framework. The specific objectives were taken from all four sources and, in addition, the investigator consulted Wise's[6] one hundred principles. The investigator adapted these specific objectives for his purpose.

[1] National Society for the Study of Education, *Thirty-first Yearbook, Part I,* "A Program for Teaching Science." Bloomington, Illinois: Public School Publishing Company, 1932.

[2] National Society for the Study of Education, *Forty-sixth Yearbook, Part I,* "Science Education in American Schools." Chicago: University of Chicago Press, 1947.

[3] "Progressive Education Association, Report of the Committee on the Function of Science in General Education," *Science in General Education.* New York: Appleton-Century-Crofts, 1938.

[4] American Council of Science Teachers, National Committee on Science Teaching, "Science Teaching for Better Living." *National Education Association,* Washington, 1942.

[5] *Op. cit.,* pp. 28–9.

[6] Harold E. Wise, "A Synthesis of the Results of Twelve Curricular Studies in the Field of Science Education—II." *Science Education,* 27 (September-October 1943), pp. 67–76.

From this list of objectives the investigator extracted those which are the primary concern of physical science. These were then examined for their appropriateness for training elementary school teachers. All of them were retained, since in the judgment of the investigator, education in the elementary school is general education. A number of statements which support this judgment from leaders in the field of science education are cited in the thesis itself. The investigator then analyzed this list for objectives of such a nature that laboratory experiences can make a significant contribution toward their attainment by the student. One of the primary considerations which the investigator kept in mind in making these judgments was the background of students entering a teachers college. As a basis for this an investigation of such background was made and is reported in the thesis.

2nd phase. Development of criteria for selection of laboratory experiences suitable for an integrated course in physical science designed for the education of elementary school teachers.

The sources of the criteria were: Chapter 13 of the Thirty-first Yearbook[7] in which Pieper lists fourteen principles of selection of content and twenty principles of organization of content for a course in general science for the junior high school; Chapter 12 of the Forty-sixth Yearbook[8] in which the application of objectives of science education to content and methods of science in the junior high school is discussed. These criteria were adapted by the investigator to the purpose for which they would be needed. An additional source of criteria was the experience of the investigator in writing experiences for his course and in the use of these experiences by students in the laboratory. A list of forty-three criteria resulted.

A jury of sixteen teachers of physical science in teachers colleges throughout the nation evaluated these criteria in terms of the list of objectives. The jury was asked to check the criteria as essential, desirable, or of little or no value in the selection of laboratory experiences. Those criteria which were checked essential by twelve or more judges were considered so; those which were checked either essential or desirable by twelve or more judges, but essential by less than twelve, were considered desirable. Six of the criteria received a rating of essential; thirty-six were judged desirable; and one of little or no value. All but the last of these will be found listed at the end of this report.

3rd phase. Selection of a set of laboratory experiences by use of the criteria.

In order to accumulate a set of laboratory experiences, the following were examined: all textbooks in general physical science on the college level, all laboratory manuals on both the secondary and the college level in general physical science, geology, astronomy, and meteorology, laboratory manuals on both levels in physics and chemistry to the point where no new experiments were obtained. None were found which met all six essential criteria in the judgment of the investigator. A set of laboratory experiences had by this time been written by the investigator and a colleague, Mr. James F. Glenn, for use in an integrated physical science course which they had developed. These were examined and revised by the investigator to meet all six essential criteria and as many of the desirable criteria in each case as was feasible. Additional experiences were written by the investigator to meet the criteria until a total of fifty-five experiences had been accumulated. The highest principles on Wise's[9] list of one hundred principles was used as a guide in the selection of the topics of these additional experiences.

Another jury of sixteen physical science teachers in teachers colleges throughout the nation was selected to evaluate these ex-

[7] *Op. cit.*, pp. 208–11.
[8] *Op. cit.*, pp. 166–80.

[9] *Op. cit.*

periences in terms of the forty-two criteria. A random sample of eighteen of the fifty-five experiences and a random sample of two of the rejected experiences were sent to the jury. Each judge checked each experience in terms of each criterion as to whether it met that criterion in his judgment. The chi square test for significance was applied to the evaluations of the sixteen judges for each experience in terms of each criterion. This means, of course, that an experience must be judged to meet a particular criterion by thirteen or more judges for acceptance of that experience in terms of that criterion. A list of the experiences by title will be found immediately following the list of criteria at the end of this report. The experiences which were evaluated by the jury are: #4, #5, #6, #7, #9, #10, #12, #13, #18, #25, #29, #41, #42, #45, #50, #52, #53, and #56 and #57. Immediately following the list of experiences at the end of this report will be found the complete presentation of one of them, Experience 42: Electric Household Appliances.

FINDINGS

The eighteen experiences met the requirements of four of the six essential criteria. Seventeen of the eighteen experiences met the requirements of five of the six essential criteria. Fourteen of the eighteen experiences met the test of the six essential criteria.

Fourteen of the eighteen experiences met eleven or more of the thirty-six desirable criteria. One experience met nineteen (a majority) of the thirty-six desirable criteria. Three of the four experiences which failed to meet all six of the essential criteria met from five to eight of the thirty-six desirable criteria.

Twelve of the thirty-six desirable criteria were met by eleven or more of the eighteen experiences. These twelve most useful desirable criteria are: #2, #3, #4, #7, #8, #9, #11, #12, #14, #19, #23, and #28.

Fifteen of the eighteen experiences met seven or more (a majority) of the twelve most useful or preferred criteria. Six of these fifteen experiences met eleven of the twelve preferred desirable criteria, and two of the experiences met all twelve of the preferred criteria. The one experience (#42) which met a majority of the whole group of thirty-six desirable criteria was one of the group of six experiences which met eleven of the twelve preferred criteria. Of the two experiences which met all twelve preferred criteria, one met seventeen of the whole group of thirty-six desirable criteria, and one met fourteen.

In the judgment of the jury, each of the two experiences which the investigator had rejected met two of the essential criteria. One of these experiences met three, and the other four, of the thirty-six desirable criteria. Each of these experiences met two of the twelve preferred desirable criteria. Thus, both of these experiences which had been rejected by the investigator (#56 and #57) rated lower, in the judgment of the jury, than did any of the eighteen experiences which had been accepted by the investigator with respect to (1) the six essential criteria, (2) the whole group of thirty-six desirable criteria, and (3) the twelve preferred desirable criteria.

CONCLUSIONS

1. The six essential criteria developed in this study are all useful in the selection or construction of laboratory experiences.

2. The thirty-six desirable criteria developed in this study are useful in varying degrees in the selection or construction of laboratory experiences.

3. The twelve most useful of these thirty-six criteria are: #2, #3, #4, #7, #8, #9, #11, #12, #14, #19, #23, and #28.

4. Of the fifty-five experiences constructed and/or revised by the investigator, the eighteen, selected at random and evaluated by a jury of sixteen teachers of physical science in teachers colleges throughout

the nation, are all better in terms of the six essential criteria, the thirty-six desirable criteria, and the twelve preferred desirable criteria, in the judgment of the jury than are two other experiences selected at random from published laboratory manuals.

5. Of these eighteen experiences the two in the field of geology are not as good, in terms of the criteria, in the judgment of the jury, as are fifteen of the other sixteen which are in the other fields of physical science.

6. In the judgment of the investigator, based upon his experience in using the experiences in a physical science course for the training of elementary school teachers, and based upon the judgment by the jury in terms of the criteria of the sampling of eighteen experiences, the fifty-five experiences presented in this study include more than enough highly desirable experiences for a course offering one two-hour laboratory period per week for thirty-six weeks.

RECOMMENDATIONS

1. It is suggested that the experienced teacher of a course in physical science for the education of elementary school teachers, who does not desire to use these fifty-five experiences—or a part of them—can use the criteria developed in this study to select or construct a set of laboratory experiences to suit the needs of his students.

2. It is suggested that the experienced teacher of a course in physical science for the education of elementary school teachers, who does not desire to use the criteria in their present form can use the ideas set forth in the criteria and/or the ideas set forth in the experiences as a basis for the selection or construction of a set of laboratory experiences to suit the needs of his students.

3. Criteria should be developed based on the needs of teachers in service as expressed by these teachers and/or their supervisors.

4. Experiences should be developed based on the needs of teachers in service as expressed by these teachers and/or their supervisors.

5. Survey studies should be made of the background in science of students entering teachers colleges and schools of education.

6. Reliable nationwide data with respect to the amount of time spent in laboratory and in class work in the physical science courses in teachers colleges and schools of education should be available.

7. Experiences which lay greater stress on the development of scientific attitudes, should be constructed.

8. Nationwide survey studies should be conducted to determine the amount and types of laboratory equipment available for the use of students in physical science courses in teachers colleges and schools of education.

ADDITIONAL INFORMATION

The thesis is not published but it is on microfilm and is available on interlibrary loan from the New York University Library. In the thesis itself will be found, in addition to a much more complete discussion of the procedure and the usual other sections:

1. In the chapter on results several tables giving the evaluations of the two juries of the criteria and of the experiences and including two tables giving the backgrounds of the judges, in what section of the country they were then teaching, and the results of their judgment of the experiences,

2. A chapter on the criteria containing a discussion of each criterion individually including comments by the members of both juries,

3. A chapter on the experiences containing a discussion of each experience individually, and

4. The complete presentations of all of the experiences (in the appendix).

CRITERIA FOR THE SELECTION OF LABORATORY EXPERIENCES

*Essential * Criteria*

Each experience must:

1. Emphasize careful observation by the student in gathering data.
2. Encourage the student to distinguish between reliable and unreliable evidence.
3. Be presented in a clear, concise manner.
4. Be so presented that the objectives are clear to the instructor and become clear to the student during the course of the experience.
5. Encourage the formulation of conclusions consistent with the data.
6. Be of such an order of difficulty that the student, through reasonable effort, may gain the satisfaction of accomplishment.

Desirable † Criteria

The experiences should:

1. Emphasize neat, legible, and accurate recording of data.
2. Emphasize cause and effect relations.
3. Have a presentation ‡ that is extensive and sufficiently descriptive, but in language that is not so technical and difficult as to discourage the student unduly.
4. Be complete enough in the presentation that the student can proceed on his own without the necessity of too much teacher direction, but not so detailed as to discourage student initiative.
5. Provide evidence which will afford the students a means of judging and measuring their progress in attainment of the objectives of science education.
6. Emphasize the recognition of sources of error in observation and measurement.
7. Be so presented that meanings, and definitions of words and scientific terms and concepts, are acquired by the student naturally during the course of the experience and as a result of it.
8. Include in the presentation instructions specific enough for performing the manipulations, but general enough to require some ingenuity.
9. Be primarily in the form of a problem or project.
10. Encourage students to call upon past experiences and to isolate elements common in past experience and the present problem.
11. Involve a generous use of thought questions rather than questions calling for information only.
12. Call for the use of equipment which can be manipulated by the students without undue danger to them under laboratory conditions.
13. Provide evidence which will afford the instructor a means of judging and measuring student progress in attainment of the objectives of science education.
14. Call for logical organization of recorded data, encouraging the student to seek relationships among the data and to formulate hypotheses.
15. Give practice in selecting the most likely hypothesis by analysis and interpretation of data, by checking the data against recognized authorities, and by collecting further data as needed.
16. Emphasize the proper use and care of equipment.
17. Include in the presentation questions calling for judgments of pertinency and significance of data for the problem.
18. Encourage the efficient and accurate use of measuring instruments.
19. Provide a maximum of opportunity for manipulation of science materials and instruments of measurement in common use.
20. Call for the construction and/or use of graphs, charts, tables, diagrams, sketches, and/or maps wherever applicable.
21. Call for devising and setting up experiments and apparatus.
22. Provide evidence which will afford the instructor a means of judging and measuring the degree of transfer of learning to new and unique situations.
23. Use in the presentation the inductive method of approach to all concepts and principles, and even to definitions wherever applicable; this to be followed by the deductive method once the principle or concept has been properly developed.
24. Give practice in the formulation of new and unique problems.
25. Call for verification of hypotheses by planned experimentation and/or inference.
26. By the liberal use of leading questions, lead the student to generalize his conclusions into life situations (application of principles to environmental phenomena of practical importance).
27. Provide for construction of some home-made and student designed equipment, in keeping with the time and materials available.
28. Call for the use of fundamental operations, such as addition, subtraction, multiplication, and division, and development of a basic understand-

* *Essential.* An experience must meet this criterion to be included in an integrated physical science course designed for the education of elementary school teachers, or, in other words, all laboratory experiences must meet this criterion.

† *Desirable.* The criterion should be used in selecting experiences, but need not be met by all experiences.

‡ *Presentation.* All the written material by which the author presents the experience to the student, including the title, directions, questions, diagrams, etc.

ing of mathematical terms such as square, proportion, area, volume, wherever applicable.

29. Give practice in analyzing and interpreting new situations in the light of conclusions reached.

30. Provide occasion for exercise of student insight in planning and checking an experiment.

31. Call for the use of essential mathematical formulas.

32. Afford opportunity for the exercise of creative abilities and for discovery and invention.

33. Include in the presentation, questions leading the student to apply one or more of the scientific attitudes to life situations.

34. Emphasize the relationship between physical quantities and their mathematical symbols.

35. Encourage independent exploration on the part of the student by calling upon him to carry on further activities (including library research and home research) outside the laboratory or classroom.

36. Suggest, where feasible, a critical evaluation of periodical and/or newspaper articles in terms of scientific attitudes and/or facts and principles.

EXPERIENCES IN PHYSICAL SCIENCE [10]

1. Density
2. Archimedes' Principle
3. Composition of the Atmosphere
*4. Relative Humidity
*5. Atmospheric Pressure
*6. Weather Forecasting
*7. Classification of Matter
8. Rocks
*9. Gem Minerals
*10. Ore Minerals
11. Soils and Soil Formation
*12. The Telescope
*13. Intensity of Light
14. The Lever: Principle of Moments, Mechanical Advantage
15. Pulleys: Work, Efficiency
16. The Inclined Plane
17. The Jackscrew
*18. Power
19. Pressure, Volume, and Temperature of a Gas
20. The Thermometer; Expansion of Liquids
21. Expansion of Solids
22. Specific Heat
23. Heat of Fusion
24. Heat of Vaporization
*25. Transfer of Heat: Conduction and Insulation
26. Absorption and Radiation of Heat
27. General Characteristics of Chemical Changes; Types of Chemical Change
28. Combinations Involving Oxygen; Speed of Reactions
*29. Ionization, Acids, Bases, and Salts
30. Carbon
31. Carbon Dioxide
32. Hard Water
*33. Solutions and Solubility
34. Electric Charges
35. Lines of Force
36. The Earth's Magnetism
37. Attraction and Polarity
38. Strength of an Electromagnet
39. Magnets and Motors
40. How Electric Currents Produce Heat and Light
*41. How the Strength of an Electric Current Is Controlled
*42. Electric Household Appliances
43. Resistance of Metals
44. The Simple Cell
*45. Electrical Equivalent of Heat
46. Electroplating
47. The Generator
48. The Transformer
49. Sound from Strings
*50. Sound from Wind Instruments
51. Reflection of Light: Mirrors
*52. Refraction of Light
*53. The Camera and Projection Lantern
54. Spectra
55. Fossils
†56. Formula of a Hydrate
†57. Galvanometer Sensitivity

[10] Authors: Allen D. Weaver and James F. Glenn.

PHYSICAL SCIENCE

EXPERIENCE 42

Electric Household Appliances

On what basis is the electric bill for the

* Evaluated by the jury.

† These two experiences were not written by the above authors, but were selected from published laboratory manuals and were evaluated by the jury.

home computed? Do you pay for electric power or energy? How much "electricity" is used by various household appliances? What is the relation between current (amperes), voltage (volts), and power (watts or kilowatts)? What is the relation between power and energy?

Bring several household appliances to school, such as a hotplate (You might find it difficult to carry an electric stove!), a toaster, an iron, a small radio, a vacuum cleaner or other appliance using a small motor. Connect in series: the two terminals of an extension cord, a light socket mounted on a wooden block and fitted with a female plug, and an AC ammeter. Connect an AC voltmeter in parallel with the mounted socket. Now plug the hotplate into this socket. When the instructor has checked your connections, plug the extension cord into the 120-volt line plug. (1) Make a table with columns headed: Name of appliance, Voltage, Current, Computed power, Rated power, Energy, Cost for 1 hr. of use. Each time you take readings or make computations throughout the experience enter them in the appropriate place in your table. Switch the hotplate on "high." What is the reading of the voltmeter? The ammeter? Multiply the amperes times the volts. Compare this number with the power rating of the hotplate in watts (stamped on the instrument). If your value of the power (volts times amperes) is less than the rated power of the hotplate, compare your voltage with that stamped on the instrument. If the actual voltage had been 120 volts, would that have increased your value of the power in watts? In that case would the current also have been greater, i.e., would more voltage also have produced more current? (2) Thus what two factors caused your value of power to be less than the rated value? (3) Is your value reliable? Explain. (4) Write a word equation for the relation between power in watts, voltage in volts, and current in amperes. Repeat the readings, computations, and comparisons with the hotplate on "medium" and on "low." Repeat for each of the other appliances you have. (5) Which of the appliances require more electric power, the heating appliances or those which have a motor in them? Repeat the readings and computations for a 100-watt bulb, and 50 and 25-watt bulbs.

What is the relation between watts and kilowatts? (6) If an appliance has a power of 2,000 watts, how many kilowatts is this? (7) What is the relation between power and energy? Electrical energy is figured in kilowatt-hours. Assume that each of the appliances in your table is used for one hour. Compute the number of kilowatt hours for each and enter it in your table under "Energy." Electric bills are paid on the basis of the number of kilowatt-hours (kw.-hrs.) of electrical energy used. Compute the cost of using each appliance for one hour at the rate of 3¢ per kw.-hr. and enter this in the table.

(8) If you have in your room a hotplate using 1,000 watts, an iron using 500 watts, and a 100-watt bulb, could you use them all at the same time on a 110-volt line, if the circuit contains a 15-ampere fuse? (9) Compute the cost of using a 500-watt iron for 6 hours a week for a month of 4 weeks, if the price is 3¢ per kw.-hr. (10) Discuss the relative efficiency of heating and lighting appliances on the one hand, and power (electric motor) appliances on the other.

AN INQUIRY INTO SOME POSSIBLE LEARNING DIFFERENTIALS AS A RESULT OF THE USE OF SOUND MOTION PICTURES IN HIGH SCHOOL BIOLOGY *

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MANY investigations have been made of the relative effectiveness of various teaching methods or techniques. In general, the measure of effectiveness has been the difference in means of the groups being compared. Although this may be a valid method of establishing the educational merits of the methods or techniques in question for total groups, the performances of various subgroups may be obscured. Method A may be demonstrated to be a superior method at a high level of statistical probability. There remain, however, large differences in the performance of individual students within the group which are readily identified from mere inspection of the data. Are there also large differences in the performances of various subgroups resulting from differences in the efficiency of methods or techniques for each subgroup? In general it may be asked, is the learning which results, relatively homogeneous and characteristic of the particular method or technique employed, or is it relatively heterogeneous and uniquely characteristic for each individual in the entire group, or are there patterns of homogeneous performances for subgroups which can be associated with differences which might be identified? It is with this latter alternative that this study is concerned.

In a recent study the investigators demonstrated that there were significant differences in achievement of different ability groups as a result of the use of a particular method of presenting materials.[1] It was demonstrated that there was a significant difference in achievement in the same direction for a group of high ability students and a group of low ability students and that no differences were observed in a group from the middle ranges of intelligence. This is not a finding which one would ordinarily expect and hence, served as a stimulant for a further analysis in an effort to determine a satisfactory explanation. The study cited above had been conducted primarily for the purpose of discovering the contribution, if any, which might be made to an understanding and application of principles of biological science, as a result of the use of educational films. The experimental design included a control group, an experimental group in which films were routinely shown, and an experimental group in which principles were stressed. Although one may accept certain objectives of instruction there are no guarantees that the learning of students is always in the dimension indicated by the stated objective. In the study cited the high and low groups achieved statistically significant superior results under the second experimental condition (E_2), whereas, the middle group did not. This leads to a postulation of the possibility that at least two different kinds of learnings may be involved. It is possible that superiority of the top group of students over

* Paper presented at Thirtieth Annual Meeting of the National Association for Research in Science Teaching, Hotel Claridge, Atlantic City, New Jersey, February 15, 1957.

[1] Kenneth E. Anderson, Fred S. Montgomery, Herbert A. Smith, and Dorothy S. Anderson, "Toward a More Effective Use of Sound Motion Pictures in High School Biology," *Science Education*, 40 (February, 1956), pp. 49–50.

their control group was achieved as a result of one kind of exceptional performance, whereas, the superiority of the low group over their control, was achieved through some other kind of superior performance. An examination of data available, indicated it might be worthwhile to check the hypothesis that two kinds of learnings actually were involved. Thus, test papers of a high I.Q. group and a low I.Q. group of students served as the basis for the detailed analysis outlined below.

It was decided to classify the items in the standardized biology test employed, the *Nelson Biology Test, Forms AM and BM*[2] into "fact-type" and "principle-type" items. A committee of three competent persons in the area of biology and science education made the determination and used as their criteria for the classification the following statements: a "principle-type" item is one in which it is possible for the knowledge of some biological principle, whether actually known or unknown to the student involved, to contribute to the securing of the correct response to the item. "Fact-type" items were those in which it did not seem that a knowledge of any biological principle whatever would aid one in securing the correct response. There were a number of items which the committee felt were not classifiable on this basis, and hence, were omitted from the final tabulations.

Following the classifications of the items into one or the other of the categories (or the rejection of the item) keys were prepared on both fact items and principle items. The examination papers for the students were then rescored in order to obtain a fact score and a principle score. Students with an I.Q. of 115 and above were included in the high group, and students with an I.Q. of 90 or below were included in the low group. This resulted in fractions of 16.2 per cent for the high group and 18.2 per cent for the low group from a total sample of 1,354 students. Intelligence test scores were obtained from the *Terman-McNemar Test of Mental Ability, Form C.*[3]

The scores obtained were then analyzed using the technique of analysis of variance and covariance as described by Wert, Neidt and Ahmann.[4] Pre-test scores and intelligence were used as control variables. The analysis for the high I.Q. group on the principles test is shown below in Tables I, II and III. In the original investigation, a control (C) and two different experimental instructional techniques had been employed. The first experimental tech-

[2] *Nelson Biology Test, Forms AM and BM.* World Book Company, Yonkers-on-Hudson, New York, 1951.

[3] *Terman-McNemar Test of Mental Ability, Form C.* World Book Company, Yonkers-on-Hudson, New York, 1941.

[4] James E. Wert, Charles O. Neidt, and J. Stanley Ahmann, *Statistical Methods in Educational and Psychological Research.* Appleton-Century-Crofts, Inc., New York, 1954.

TABLE I

SUMS, MEANS, AND CROSSPRODUCTS OF CRITERION AND CONTROL VARIABLES (PRINCIPLES KEY)

		Post-Test		Pre-Test		Intelligence	
Group	N	ΣY	$\bar{Y}$	ΣX	$\bar{X}$	ΣI	I
C	87	2663	30.61	2585	29.53	10681	122.77
E_1	73	2218	30.38	2169	29.71	8884	121.70
E_2	60	2021	33.68	1725	28.75	7287	121.45
Totals	220	6902	31.37	6479	29.45	26852	122.05

Sums of Scores Squared:
Post-Test (Y) = 224,364
Pre-Test (X) = 196.189
Intelligence (I) = 3,286,312

Sums of Crossproducts:
Pre-Test × Post-Test (XY) 204,267
Post-Test × Intelligence (YI) 845,297
Pre-Test × Intelligence (XI) 793,514

TABLE II

SUMS OF SQUARES AND CROSSPRODUCTS IN DEVIATION FORM FOR TOTAL AND FOR SUBGROUPS

Source of Variation	Σy^2	Σx^2	Σi^2	Σyi	Σxi	Σxy
Total	7829.44	5382.45	8903.35	2876.53	2722.60	3001.10
Within Subgroups	7386.95	5342.03	8827.63	2928.18	2687.69	3134.53

nique (E_1) involved the use of films in biology classes in the usual way. The second experimental approach (E_2) involved the use of films with principles stressed.

The normal equations below were employed to compute the partial regression coefficients for both total and subgroups.

$$\Sigma yx = a_1\Sigma x^2 + a_2\Sigma xi$$
$$\Sigma yi = a_1\Sigma xi + a_2\Sigma i^2$$

These yield values of .18050 and .18796 for a_1 and .46627 and .49220 for a_2 for total and within partial regression coefficients respectively. These values were used to compute the sums of squares for residuals for total and for within. The results and the test of significance are shown in Table III.

TABLE III

TEST OF SIGNIFICANCE OF INFLUENCE OF VIEWING FILMS ON LEARNING OF PRINCIPLES OF SCIENCE

Source of Variation	Degrees of Freedom	Residuals Sum of Squares	Mean Square
Total	217	5864.34	
Within	215	5283.48	25.04
Difference	2	580.86	290.43

$$F = \frac{290.43}{25.04} = 11.598 \quad P < .01$$

The results of the analysis yielded a statistically significant difference among the three instructional methods at the 1 per cent level of confidence for the high groups on the principles sub-test. The low group showed a difference significant at the 5 per cent level of confidence on the principles sub-test. Both differences were in favor of the films-with-principles stressed method. The assumptions basic to the analysis were fully met with the superior group. In the case of the low group, the assumptions were met only in part and hence the latter finding must be accepted with reservation. The differences among instructional methods on the fact sub-scores were not significant for either group. Thus, the analysis offers no support to the hypothesis that two different kinds of learning were involved. It had been hypothesized that the analysis might reveal that the films had been especially valuable to the low group in helping them to acquire facts, whereas the high group had been especially benefitted in learning principles. However as shown in Table IV the benefit for both groups was largely in the improvement on principle-type items.

Table IV presents a somewhat different view. Mean test scores for the total test are shown. The scores of the low and high groups have been adjusted to compensate for the omission of items which could not

TABLE IV

MEAN PRE-TEST AND POST-TEST SCORES OF THE LOW, HIGH, AND TOTAL GROUPS ON THE NELSON BIOLOGY TESTS, FORMS A AND B

	Low Group *			High Group *			Total Group		
Group	Pre-Test	Post-Test	Gain	Pre-Test	Post-Test	Gain	Pre-Test	Post-Test	Gain
C	23.57	24.98	1.41	41.69	47.74	6.05	31.55	34.76	4.21
E_1	22.70	23.51	.81	41.76	47.03	5.27	31.93	35.08	3.15
E_2	22.35	25.79	3.44	40.97	52.04	11.07	31.34	36.38	5.04

* Scores have been adjusted for low and high groups to compensate for the fact that some items had been omitted from the test because they were unclassifiable.

be classified into fact or principle types. The assumption made in the adjustment was that the proportion of correct answers would have remained the same for each subgroup had the items been included.

The information in Table IV clearly reflects the conclusions cited in Anderson's *et al.* original study, i.e., the relatively greater effectiveness of method E_2 *within* each intelligence category for the low and high groups as compared to the middle group.[5] The present analysis has failed to establish any satisfactory rationale for these observations.

The establishment of statistically significant differences does not by any means establish the educational significance of observed differences. Except for the high E_2 group the average improvement of the two groups was of the order of .5 of a z-score. The mean standard scores for the total test, together with the improvement in z-score and percentile standings are shown in Table V. The improvement seems meager after a year's study in biology. Certainly the amount of biology known to students, as measured by the test employed when students began to study this subject seems to constitute an unreasonably high proportion of what they knew when they had finished the course. It may be argued that the test provides a measure of only a small part of the objectives of high school biology. However, it is a moot question as to whether objectives involving other dimensions of learning in biology are anymore satisfactorily attained. Evidence bearing on this point would be a welcome addition to the literature.

[5] *Op. cit.*

TABLE V

MEAN STANDARD SCORES AND CORRESPONDING PERCENTILE VALUES FOR LOW, HIGH AND TOTAL GROUPS ON PRE- AND POST-TESTS, WITH IMPROVEMENT EXPRESSED IN z-SCORE UNITS *

	Low Group			High Group			Total Group		
	C_1	E_1	E_2	C_1	E_1	E_2	C_1	E_1	E_2
Pre-Test Standard Score	92	92	90	115	115	114	104	104	103
Post-Test Standard Score	97	97	98	124	123	128	110	110	111
Pre-Test Percentile	18	18	15	80	80	77	50	50	46
Post-Test Percentile	31	31	35	93	92	96	67	67	69
Improvement in z-Score Units	.37	.37	.59	.67	.57	1.04	.48	.48	.59

* Standard Scores on the *Nelson Biology Test* are based on a mean of 104 and a standard deviation of 13.5.

THE INTERACTIONS OF SOCIETY AND SCIENCE

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SCIENCE is usually credited with having completely changed our civilization and social patterns. However, the influence of social factors on the development of science is too often neglected in our considerations. A more correct view is that society and science interact upon each other and grow in a mutually dependent relationship. It is therefore society's responsibility to guide the future development of science into patterns that will make for a better world. An examination of how past social conditions affected the growth of science may suggest a plan for future action.

In primitive cultures, of which we can only conjecture, since objective evidence is lacking, man was forced to live as an opportunistic searcher. Whatever food, clothing, or shelter he found had to be utilized where he found it and in an unimproved condition. Later he settled nearer

to his source of supplies. He learned the habits, migrations, and anatomy of the animals he hunted. He then advanced to the stage of adapting nature's bounty to his own needs by fashioning crude shelters, clothing, and tools from rocks, trees, plants, and animals. When he learned to domesticate animals, a great advance was made but with it were added many new problems of housing, feeding, and caring for them. Similarly, primitive agriculture gave benefits but made demands upon early man's ingenuity. During this time, early man was gathering bits of correct information about soils, seeds, plants, trees, minerals, crude tools, fire, and weather. This learning is considered as being the science of its time. The struggle for survival forced man to win from nature a few of its less cryptic secrets.

Village life forced many problems upon early man. Protection against adverse weather conditions and wild animals had to be improvised. Then there were problems of water supply, food storage, simple sanitation and means of travel. As living conditions improved, the populations increased and with this, family and tribal communities grew. Group living set the stage for new social pressures, such as, demands for improvement in community living conditions.

Helplessness in the face of disease, hunger, and death made man look outside himself for aid. Fear and uncertainty fostered hope in miracles and magic. Certain members of the community, by self-appointment or by election, undertook to study and administer these magical rites. The medicine man and the sorcerer were most highly esteemed because of the great value their society placed upon their purported abilities. The demands of society impelled these magic doers to seek new incantations, symbols, and materials. Though only a very few searched, and infinitely fewer found, it is believed that the world's knowledge of plants, animals, minerals, and processes was enhanced by these seekers. In primitive societies, the needs of the community set the scheme for the searcher and improviser. If he was successful, then his community profited.

While some magicians grubbed in the earth for their miracle performing stuffs, others looked to the heavens for magical powers. Watching the moon and the stars in their steady courses gave some dreamers the idea that the destinies and fates of men were controlled by these bodies. In their eternal search for security, these star gazers tried to read predictions from the star patterns and motions. This increased the then available knowledge of astronomy even though many misconceptions and superstitions were introduced.

Ancient society had a use for magicians and sorcerers. Kings consulted them for auguries. Townsmen were thrilled by their stunts. By manipulating gadgets and materials, they attained startling and often inexplainable results. Through the centuries they compiled many bits of information which eventually got into the fund of common knowledge. That they survived for so many centuries indicates that they met with society's approval.

"Magic, religion, and astrology are three forerunners of science, though their exact historical relation with science and with each other are unknown," states Damphier-Whetham. "Whatever be the exact relation between the three, magic seems to be the primitive matrix out of which both religion and science emerged," he continues. A society that sustained the practice of magic was able to profit from the off-shoots of it.

Magic's great contribution to the advancement of science lay in its nature of striving to compel external things to follow man's will. This encouraged early experimenters to seek novel and difficult effects. It encouraged alchemists to search for the "elixir of life," a magical potion that could cure all human ills. Though unsuccessful in this, many useful chemicals and cures were found in the search. Similarly unsuccessful was the search for the "philosophers stone" to turn baser metals into gold. Sim-

ilarly valuable were its concomitant discoveries.

Slavery existed in the Babylonian, Egyptian, Greek and Roman civilizations of antiquity. This greatly retarded the advancement of science because experimentation was practically nonexistent inasmuch as it required manual labor. Working with one's hands was considered to be disgraceful to a freeman and fit only for a lowly slave. Plato classified science into two parts: theoretical and practical. He believed gentlemen could take an interest in pure science but not in the practical. The system of slavery tended to separate theory from practice. The study of anatomy and surgery suffered disastrously from this. Scribes, like present day white collar workers, looked down with disdain upon artisans and mechanics. Science did not advance commensurately to the levels of logic, mathematics, and philosophy existent at the time. Without experimentation, science remained an amorphous mixture of fact and fancy unable to evolve into a vigorous growing body of knowledge.

When slavery declined, because of economic conditions and the rise of Christianity, manual labor was not held in such low repute. As a result, the artisan and craftsman were encouraged to innovate and experiment. Citizens of means and influence took greater interest in the mechanics and materials of the work-a-day world. Slavery destroyed incentive and stifled advancement. The disappointing results of German and Italian science under the recent dictatorships illustrate this point.

The Romans were deeply interested in country life, as the writings of Virgil and Pliny indicate, and as a result were very observant of plants and animals. This added significantly to the store of man's knowledge.

The military caste of Rome demanded good roads, water and sewage systems, hospitals, and weapons. This and the need of imposing public buildings stimulated research in engineering.

Early Greek science, born in a more peaceful environment and influenced by the occultism of the East, tended to be more philosophic and abstruse.

The disintegration of Roman society and its culture brought effective scientific research to a halt but increased the practice of magic, astrology, and occult sciences. The chaotic European civilization between this time and the Renaissance generated a type of wishful thinking in the people. The fear and uncertainty of this period reflected itself in the reversion towards magic and miracles. The synthesis of Aristotelean philosophy and the theology of Thomas Aquinas, coupled with the growing influence of the Church added to the inclination toward mysticism. Philosophy was the hand maiden of theology but the jailer of experimentation. The extensive practice of magic during the middle ages produced some useful astronomical data from the practices of the astrologers but the results were not comparable to the efforts.

Manual labor was again considered disreputable, experimentation languished. Medicine and architecture declined because learned men preferred disputation and relegated manipulation to their servants. Science instead of raising civilization from its depression was pulled down by it.

During the Dark Ages the lamps of learning flickered feebly in the monasteries. Benedict introduced reforms in the regimen of the monks. He required that God be honored by either manual or intellectual labor, in addition to prayer. Benedict's influence restored the dignity of labor. This respectful attitude towards manual work later made possible the rebirth of experimental science. The influence of Arabian-Jewish culture in Spain and North Africa gave new life to the languishing science of the times. Jewish court physicians contributed significantly to the knowledge of medicine and in addition were spreading the current knowledge of optics, alchemy, and mathematics. A pre-

vious mingling in Alexandria of Greek and Jewish influences point to the benefits of international traffic in ideas. A modern illustration of this is the variety of national origins and cultures of our successful atomic bomb scientists.

Feudalism exerted its effect upon the development of science. The manors required many craftsmen and artisans. Lords of the manor had problems of agriculture, animal husbandry, instruction, and metallurgy. Alchemists and doctors were engaged by the courts. Secrets of weaving, dyeing, brewing, glass-making, and medication were eagerly sought after. Research was kept alive by this incentive. Some materials and processes were introduced which later were useful in advancing experimental science.

In its later stages, feudalism inspired the rivalry of the merchants and city tradesmen who rebelled against feudal restrictions upon their liberties and commerce. The bourgoisie gained great wealth and influence and required the services of educated clerks capable of assuming the responsibilities of management. This created a demand for institutions of learning other than religious ones, where the new type of administrator could be trained. During the twelfth century, the University evolved to fill this need. It took root in the populated Cathedral towns where an abundant supply of secular monks was available as teachers and where ample living quarters were obtainable for the students. The early curricula included astronomy and alchemy which were of practical value to future mercantilists.

"The Universities were progressive in science during the twelfth century," according to Crowther. "They spread the new knowledge of Greek and Moslem science. When this had been accomplished, they were able to make many more contributions, owing to their social perspective. They aimed at transference of manual workers into the literary class, so their atmosphere was antagonistic to manual work, and therefore to experiment. . . . The rapid intellectual development slowed down in the fourteenth century. After the scholars at the Universities had assimilated earlier science, they could not advance rapidly as they did not include experimental work in their system." However, thinkers like Bacon and William of Occam were contributing great theoretical principles and other less renowned scholars, reacting to the needs of the sea-going merchant class, were finding facts about weather, tides, the calendar, and astronomical tables.

The interests of the mercantile classes determined the direction in which intellectual energies were spent. Robert Boyle, an immensely able and wealthy man, broke down the prejudices of the upper classes towards crafts and experimentation. Others like him joined to form the Royal Society of England which was granted a charter by Charles II in 1662. To it were attracted many interested "gentlemen" who zealously investigated scientific problems. These were generally related to the needs of housing, medicine, trade, or navigation. After the Great Fire of London and the Plague, new building materials, house designs, and street and drainage plans were investigated by them. Crowther mentions that, "The scope of the plans and the profusion of experiments and achievements (of the Royal Society) show that the development could have been due only to a powerful social movement and not to the accidental inspiration of a few talented men." Robert K. Merton, in discussing the growth of science in the seventeenth century has pointed out that the general themes of science were set by the sociological conditions while particular subjects within these themes were determined by the individual abilities of men like Boyle, Hooke, Newton, Wren, and Halley.

The shipping and colonization rivalry between the powerful states of Europe's Atlantic coast, in the seventeenth and eighteenth century, launched a desperate

race to find an accurate means of determining longitude on ships at sea. A method based on the motion of the moon was suggested by Newton and others, but these were not accurate enough. A reward equivalent to one hundred thousand dollars was offered by the British government in 1712 for a satisfactory solution. The lunar theory became the outstanding scientific problem of the eighteenth century and as a result, astronomy became the senior science in all British Universities. Newton's "Principia Mathematica," according to Crowther "may be regarded to a large extent as a theoretical synthesis of the problems set in gravity, circular motion, planetary and lunar movement, and the shape and size of the earth by the demand for better navigation." "De Magnete," the great classic on magnetism, by William Gilbert, Queen Elizabeth's physician, was inspired chiefly by the practical demands of navigators.

The eighteenth century witnessed three great upheavals of social equilibrium and thought in the French, American and Industrial revolutions. Sedgwick and Tyler state, "If the French Revolution had done no more than to upset as it did, the social equilibrium of the centuries, its effect in stimulating inquiry and generating doubt in almost every direction could not have failed to further scientific studies and promote wholesome investigation into the fundamental relations of man and nature." This period produced a class of radical, non-conformist, scientist-industrialists in England, like Watt, Wedgwood, and Bolton. They were closely associated as friends, industrial consultants, and as members of the intellectual Lunar Society with great scientists such as Black and Priestly. In France, Diderot and Alembart supervised the compilation of the French Encyclopedia, a dictionary of arts, sciences and manufactures which exerted a great influence upon the education of French scientists, including Lavoisier.

The improvement of the steam engine by Watt in 1765 was in response to demands made by the English textile industry. The advances in knowledge in the field of heat and thermodynamics by Joule, Mayer, Clausius, Kelvin, Gibbs, Carnot, and others were influenced by problems related to steam engines such as expanding gases, evaporation, and condensation.

With the rise of industrialism, great interest was given to the study of heat and electricity in the English universities. Navigation and astronomy, sponsored by a mercantile economy, declined in curricular importance. Businessmen of vision saw great profits in signal devices for the newly invented railway system. Governments with far flung colonies were deeply interested in telegraphy and trans-oceanic cables. These social pressures spurred research in telegraphy and steam transportation. As the industrial tempo increased, new demands were made upon scientists and new opportunities were seized by inventors. Industry began to employ engineers to do research on their specialized problems. Pure research was influenced by new inventions. Edison's invention of the electric light, spurred research in electrical discharges through high vacua and gases.

Modern scientific research is very expensive. Atom smashing machines cost hundreds of thousands of dollars. The lonely amateur or the modestly endowed university department can not be expected to make such expensive investments. Who is to pay for research? Who is to decide which researches are needed? From present indications it appears that the national government will have to sponsor research in pure science and in science as it applies to military needs. Private industry has in the past paid for its specialized research and will continue to do so in the future. The university research program should be subsidized by the government.

The value of research was dramatically brought to the public's attention by the story of the space satellites. Our govern-

ment officials are vitally aware of the necessity of having a carefully organized, nation-wide system of research even though the first legislation to this effect was vetoed by President Truman on the grounds that the government would not be in full control, although it was financially supporting it. A bill to support the advancement of a national science program was eventually passed and signed.

Russia, England, and France for many years have realized how dependent their economy is upon scientific progress. They are also cognizant that scientific progress depends upon the society in which it flourishes. America, too, is accepting this philosophy. To quote Crowther, "Science is like a powerful limb on the body of society, which to some extent possesses its own life and growth and can accomplish many things, but it is not an independent organism, and dies when the social body that supports it is diseased."

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A STUDY OF THE VARIABILITY OF EXCEPTIONAL HIGH SCHOOL SENIORS IN SCIENCE AND OTHER ACADEMIC AREAS * †

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INTRODUCTION

A CONSIDERABLE volume of literature on exceptional children has been built up during the past decade. Current literature reflects treatment of all exceptional categories, but it has dealt principally with mental retardation. Also, considerable study has been made regarding the variability of school children on standardized tests, but the variability of those at the extremes has been given less attention. Therefore, it seemed important to study the lower and upper ends of the spectrum of academic achievement and intelligence for the purpose of gaining a better understanding of variability existing in groups frequently regarded as homogeneous. Such an analysis might permit educators to be in a better position to offer guidance to these individuals and thus probably effect a greater realization of their academic potentials.

The problem, therefore, became one of securing an adequate sample or one which would provide sufficient cases at the extremes in order for valid conclusions to be drawn from the treated data. Such a sample was available in the files of the authors of this study.

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† Paper presented at Thirtieth Annual Meeting of the National Association for Research in Science Teaching, Hotel Claridge, Atlantic City, New Jersey, February 16, 1957.

During the school year 1951–52, a representative sample of 1445 Kansas high school seniors took the following tests: (1) *Essential High School Content Battery,*[1] and (2) *Terman-McNemar Test of Mental Ability, Form C.*[2] The achievement battery consists of four sub-tests designated as Science, Mathematics, Social Science, and English. The original sample of Kansas high schools, from which the data for this study were obtained, was selected by means of stratified-proportional sampling on the basis of high school enrollment. The sample as drawn contained 49 Kansas high schools enrolling 1445 seniors. There were 716 males and 729 females in the total group.

PURPOSES OF THE STUDY

The purposes of this study were:

1. To determine the percentages of seniors designated as exceptional in science achievement in both male and female categories.
2. To determine the relative contribution of schools of varying size to the exceptional groups in science achievement.
3. To obtain the degree of relationship existing between science achievement and achievement or ability in the other four areas for the groups designated as exceptional in science achievement. The other four areas were mathematics, social studies, English, and intelligence.
4. To describe the variability in science achievement of those seniors designated as exceptional in achievement or ability as measured by the other four tests.
5. To describe the variability in achievement or ability as measured by the other four tests of those seniors designated as exceptional in science achievement.

A senior was designated as exceptional if his score on a particular test placed him in the upper or lower ten per cent of the frequency distribution for that test. Thus, for the purposes of this study, there were ten exceptional groups of seniors. These were the upper and lower ten per cents in: (1) science, (2) mathematics, (3) English, (4) social studies, and (5) intelligence.

[1] *Essential High School Content Battery.* World Book Company, Yonkers-on-Hudson, New York, 1951.

[2] *Terman-McNemar Test of Mental Ability, Form C.* World Book Company, Yonkers-on-Hudson, New York, 1941.

SECURING THE EXCEPTIONAL GROUPS

The achievement test scores and the intelligence test scores of the 1445 seniors were arranged into five frequency distributions, each based on one of the five areas tested. The range, the mean score, and the standard deviation were calculated for each distribution. These values appear in Table I along with the range of scores in the lower and upper ten per cents for each of the areas tested. In order to secure the 145 individuals for the lower and upper ten per cents for each of the areas tested, it was necessary to pick several cases at random from the group who scored exactly at the cutting score which was established. For example, the range of scores in the lower ten per cent group in mathematics was 5 to 14 but this range included 172 cases, 119 of which had scores of 13 or below. Thus, 26 cases were picked at random from among the 53 at the score of 14 to secure a sample of 145 cases. The same procedure was followed in the other nine instances. The five test scores, sex, and size of school were tabulated for each of the 145 individuals in each of the ten per cent groups. These ten sets of test scores and associated data afforded the bases for the analyses made and described in the next section of this report.

ANALYSIS OF THE DATA AND RESULTS OBTAINED

Numbers and Percentages of Males and Females in the Lower Ten Per Cent Groups and the Upper Ten Per Cent Groups in the Five Areas Tested

There were 716 males and 729 females in the group of 1445 seniors tested. The percentages were 49.55 and 50.45, respectively. The difference was not significant at the 5 per cent level.

There were 145 graduating seniors in the lower ten per cent and the upper ten per cent of each of the five areas tested. The number and the percentage of males and females in each of the five achievement

TABLE I

STATISTICAL INFORMATION PERTAINING TO THE SCORES OF THE 1,445 KANSAS HIGH SCHOOL SENIORS IN THE FIVE AREAS TESTED

	Mathematics	*SCIENCE*	Social Studies	English	Intelligence
Number of seniors tested	1,445	1,445	1,445	1,445	1,445
Mean score	24.42	34.49	41.34	173.62	109.19
Standard deviation	9.67	10.47	11.54	24.66	23.37
Range of scores	5 to 65	5 to 65	13 to 85	42 to 236	35 to 159
Range of scores in lower ten per cent	From 5 to 14 (with 26 cases from scores of 14) *	From 5 to 22 (with 5 cases from scores of 22)	From 13 to 26 (with 23 cases from scores of 26)	From 42 to 142 (with 4 cases from scores of 142)	From 35 to 78 (with 10 cases from scores of 78)
Range of scores in the upper ten per cent	From 65 to 38 (with 17 cases from scores of 38)	From 65 to 49 (with 13 cases from scores of 49)	From 85 to 59 (with 11 cases from scores of 59)	From 236 to 204 (with 5 cases from scores of 204)	From 159 to 139 (with 3 cases from scores of 139)

* Twenty-six cases were picked at random from the 53 scores of 14 to secure a sample of 145 cases. The same process was used in the other nine instances.

groups were tabulated. The results appear in Table II.

There were 80 males and 65 females in the lower ten per cent group in science or 55.2 per cent males and 44.8 per cent females. The difference of 10.4 was not significant at the 5 per cent level.

There were 98 males and 47 females in the upper ten per cent group in science or 67.6 per cent males and 32.4 per cent females. The difference of 35.2 per cent in favor of the males was significant at the 1 per cent level.

TABLE II

NUMBERS AND PERCENTAGES OF MALES AND FEMALES IN THE LOWER AND THE UPPER TEN PER CENT OF THE FIVE AREAS TESTED

	Mathematics		*SCIENCE*		Social Studies		English		Intelligence	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
The Lower Ten Per Cents										
Number	54	91	80	65	80	65	109	36	74	71
Percentage	37.2	62.8	55.2	44.8	55.2	44.8	75.2	24.8	51.0	49.0
Difference	25.6		10.4		10.4		50.4		2.0	
In favor	Females		Males		Males		Males		Males	
Probability	$P < .01$		$P > .05$		$P > .05$		$P < .01$		$P > .05$	
The Upper Ten Per Cents										
Number	109	36	98	47	90	55	47	98	74	71
Percentage	75.2	24.8	67.6	32.4	62.1	37.9	32.4	67.6	51.0	49.0
Difference	50.4		35.2		24.2		35.2		2.0	
In favor	Males		Males		Males		Females		Males	
Probability	$P < .01$		$P < .01$		$P < .01$		$P < .01$		$P > .05$	

TABLE III

NUMBERS AND PERCENTAGES OF EXCEPTIONAL SENIORS IN EACH AREA TESTED IN RELATION TO THE CATEGORIES ACCORDING TO SIZE OF SCHOOL

School Enrollment	Graduating Seniors	Expected Number In 10%		Found in Mathematics		FOUND IN SCIENCE		Found in Social Studies		Found in English		Found in Intelligence	
				Lower 10%	Upper 10%	Lower 10%	Upper 10%	Lower 10%	Upper 10%	Lower 10%	Upper 10%	Lower 10%	Upper 10%
Group A	93	9.3	N	5	10	5	11	14	9	8	13	10	11
Under 50			%	53.8	107.5	53.8	118.3	150.5	96.8	86.0	139.8	107.5	118.3
Group B	238	23.8	N	27	29	33	17	29	15	40	19	32	17
50–99			%	113.4	121.8	138.7	71.4	121.8	63.0	168.0	79.8	134.5	71.4
Group C	277	27.7	N	22	26	27	31	36	19	19	29	38	27
100–199			%	79.4	93.9	97.5	111.9	130.0	68.6	68.6	104.7	137.2	97.5
Group D	225	22.5	N	21	18	25	20	26	18	21	16	31	26
200–299			%	93.3	80.0	111.1	88.9	115.6	80.0	93.3	71.1	137.8	115.6
Group E	412	41.2	N	50	36	38	39	24	47	36	41	24	49
300–599			%	121.4	87.4	92.2	94.7	58.3	114.1	87.4	99.5	58.3	118.9
Group F	200	20.0	N	20	26	17	27	16	37	21	27	10	15
600–over			%	100.0	130.0	85.0	135.0	80.0	185.0	105.0	135.0	50.0	75.0
Chi-square	(Expected frequencies versus observed frequencies)			5.48	4.65	6.56	5.53	14.53	22.16	14.66	6.83	22.10	5.54
Probability				$P>.30$	$P>.30$	$P>.20$	$P>.30$	$P<.02$	$P<.001$	$P<.02$	$P>.20$	$P<.001$	$P>.30$

Numbers and Percentages of Exceptional Seniors in Relation to the Size of High Schools

The data for the 49 high schools in the sample used in this study were separated on the basis of enrollment into six groups. Group A consisted of the twelve schools with enrollments under 50. Group B consisted of the seventeen schools with enrollments from 50 to 99. Group C consisted of the ten schools with enrollments from 100 to 199. Group D included the five schools with enrollments from 200 to 299. The four schools with enrollments from 300 to 599 were included in Group E. Group F consisted of one school, representing high schools with enrollments of 600 or over.

Each senior in the ten per cent groups was placed in one of the six categories according to size of school for each of the five areas tested, as shown in Table III. The purpose of this step was to obtain the relative proportion of the expected number of cases for each cell of the table. For example, the combined enrollment in the twelve schools of Group A was 93. Ten per cent of the group, or 9.3 cases, should be found in each of the lower and upper ten per cents of each of the five frequency distributions.

Chi-square values were computed using the expected number and the observed number for each school enrollment bracket for each of the ten per cent groups. These values appear in Table III. The chi-square values in Table III lend support to the statement that schools of varying size contributed as expected to the lower and upper ten per cent groups in science. The chi-square values for the lower and upper groups had probability values of $P > .20$ and $P > .30$ respectively. It should be pointed out that the high schools with enrollments under 50, from 100 to 199, from 300 to 599 and 600 or over contributed less than expected to the lower ten per cent group in science. The reverse was true for the schools having enrollments from 50 to 99 and from 200 to 299. The high schools with enrollments from 50 to 99, 200 to 299, and 300 to 599 contributed less than expected to the upper ten per cent group in science. The reverse was true for the schools having enrollments under 50, from 100 to 199, and from 600 or over.

On the basis of significant chi-square values and the relative contributions of each category according to size of school, it would appear from Table III, that in general the schools in the smaller-size categories contributed more than the schools in the larger-size categories to the lower groups in social studies, English, and intelligence. The reverse was true for the upper group in social studies.

In order to complement the chi-square values obtained, rank order correlations were computed between size of school and the relative contributions of the categories according to size of school to the lower and upper ten per cent groups of the five areas tested. Rank order correlations as they appear in Table IV were computed according to the following method as illustrated for the lower group in science.

Size of School	Rank	Percentage as Expected	Rank	D	D^2
Under 50	6	53.8	6	0	0
50–99	5	138.7	1	4	16
100–199	4	97.5	3	1	1
200–299	3	111.1	2	1	1
300–599	2	92.2	4	—2	4
600–over	1	85.0	5	—4	16
				0	38

$$r = 1 - \frac{6\Sigma D^2}{N^3 - N} = 1 - \frac{6\ (38)}{216 - 6} = -\ 0.09$$

The correlations thus obtained for the lower groups and upper groups in science were a $-.09$ and a $+.26$. Both correlations were not significant. Thus it would appear that there was no relationship between size of school attended and achievement in science for the two exceptional groups.

The correlations obtained for the lower and upper groups for the other areas, were:

.54 and — .03 for mathematics, — .89 and .66 for social studies, .26 and — .14 for English, and — .43 and .03 for intelligence. Only the correlations for social studies had low enough probabilities to consider them as indicative of the existence of definite relationships.

scatter diagrams revealed a slight degree of curvilinearity. Undoubtedly, the chi-square values which would have been obtained in the calculations of contingency coefficients, would have revealed the same non-significance or significance of relationships as did the product-moment correlations.

TABLE IV

RANK ORDER CORRELATIONS BETWEEN SIZE OF SCHOOL AND THE RELATIVE CONTRIBUTIONS OF THE CATEGORIES ACCORDING TO SIZE OF SCHOOL TO THE LOWER AND UPPER TEN PER CENTS

		Mathematics	*SCIENCE*	Social Studies	English	Intelligence
Lower ten	r	+.54	−.09	−.89	+.26	−.43
per cents	Prob.	.15	.46	.02	.33	.21
Upper ten	r	−.03	+.26	+.66	−.14	+.03
per cents	Prob.	.50	.33	.09	.40	.50

Correlating the Scores that Placed Graduating Seniors in a Lower or in an Upper Ten Per Cent with Their Scores in the Other Areas Tested

There were five groups of 145 seniors representing the lower ten per cent for each of the five areas tested. There were the same number of groups and seniors in the upper ten per cent. The scores which placed seniors in an exceptional group were recorded as were their associated scores for the other four areas tested. The scores which placed 145 seniors in an exceptional group were correlated with each of the series of associated scores for the other four areas tested. This resulted in 20 correlations from the five groups representing the lower ten per cent for the five areas tested. The same number of correlations were obtained from the upper ten per cent groups for the five areas tested. The correlations from all exceptional groups are summarized in Table V. One must remember that the correlations appearing in Table V were expected to be much lower than if the entire sample of 1,445 cases had been used for reasons that: (1) we were dealing with restricted ranges of scores, (2) the responses of the lower groups to the test items were probably in many instances chance responses, and (3) all the

Sixteen of the correlations which appear in Table V involved the correlation of science scores with scores in the other areas. Positive-non-significant correlations were obtained for the lower ten per cent in science with social studies, English, and intelligence. A low-positive-significant correlation was obtained for the lower ten per cent in science with mathematics. Positive-significant correlations were obtained for the upper ten per cent in science with mathematics, social studies, English, and intelligence. Although positive-significant correlations were obtained between science and mathematics of .170 and .400 for the lower and upper ten per cent groups in science, the difference between the correlations was significant at the 5 per cent level.

Although positive-significant correlations were obtained between intelligence and science as shown in Table V of .316 and .249 for the lower and upper groups in intelligence, the correlations were not significantly different.

Positive-non-significant correlations were obtained between science and the lower ten per cent groups for mathematics, social studies, and English. The correlations of science with the upper ten per cent of these three groups yielded positive significant correlations.

TABLE V

THE RESULTS OF CORRELATING THE SCORES THAT PLACED SENIORS IN A LOWER OR AN UPPER TEN PER CENT OF AN AREA WITH THEIR ASSOCIATED SCORES FROM EACH OF THE OTHER FOUR AREAS TESTED

	Series 1		*SERIES 2*		Series 3		Series 4		Series 5	
	Mathematics Scores		*SCIENCE SCORES*		Social Studies Scores		English Scores		Intelligence Scores	
	Lower 10%	Upper 10%	Lower 10%	Upper 10%	Lower 10%	Upper 10%	Lower 10%	Upper 10%	Lower 10%	Upper 10%
Scores in Mathematics	.....	.....	*.170**	*.400†*	.067	.177*	.113	.313†	.185*	.121
Scores in Science	*.044*	*.357†*	.....	.....	*.077*	*.219†*	*.066*	*.469†*	*.316†*	*.249†*
Scores in Social Studies	.037	.337†	*.059*	*.322†*	....	.....	.011	.316†	.177*	.205*
Scores in English	.103	.190*	*.153*	*.259†*	.214†	.314†	....	.....	.296†	.265†
Scores in Intelligence	.096	.238†	*.146*	*.254†*	.119	.215†	.111	.390†	.....	.....

* Significant at the 5 per cent level.
† Significant at the 1 per cent level. N = 145

Distributions of Science Scores of Seniors Whose Scores Placed Them in the Lower or Upper Ten Per Cents in Mathematics, Social Studies, English, and Intelligence

Seniors placed in the iower and upper groups in mathematics, social studies, English, and intelligence were distributed as to scores in science. Each science score obtained was tallied into one of the four categories based on the total distribution of science scores for the 1,445 students. The categories or ranges of science scores were as follows: lower ten per cent, 40 per cent

TABLE VI

NUMBERS OF SENIORS WHOSE SCORES IN MATHEMATICS, SOCIAL STUDIES, ENGLISH, AND INTELLIGENCE PLACED THEM IN THE LOWER TEN PER CENTS OF THOSE DISTRIBUTIONS DISTRIBUTED AS SHOWN ON THE BASIS OF THEIR SCIENCE SCORES INTO THE RANGES INDICATED

	Mathematics		Social Studies		English		Intelligence	
Ranges of Science Scores *	N	%	N	%	N	%	N	%
Lower 10 per cent Range of Scores: 5 to 22	45	31.03	69	47.59	59	40.69	65	44.83
40 per cent below the mean Range of Scores: 22 to 34.49	79	54.49	70	48.28	71	48.97	76	52.41
40 per cent above the mean Range of Scores: 34.49 to 49	20	13.79	6	4.13	14	9.65	4	2.76
Upper 10 per cent Range of Scores: 49 to 65	1	0.69	..	.....	1	0.69	..	.....
Totals	145	100.00	145	100.00	145	100.00	145	100.00

* Based on the total distribution of science scores for the 1,445 seniors.

below the mean, 40 per cent above the mean, and the upper ten per cent. The same procedure was followed for each of the other four areas. However, the results are not reported in this paper. Tables VI and VII, and Figures 2–5, reveal that not all of the students from the ten per cents of the other four areas remained in the lower or upper ten per cents in science. In fact, they distributed themselves rather widely over the entire range of scores. Figure 1 shows the distribution of science scores for the entire group of 1,445 seniors.

The relative contributions of the lower ten per cents in mathematics, social studies, English, and intelligence to the:

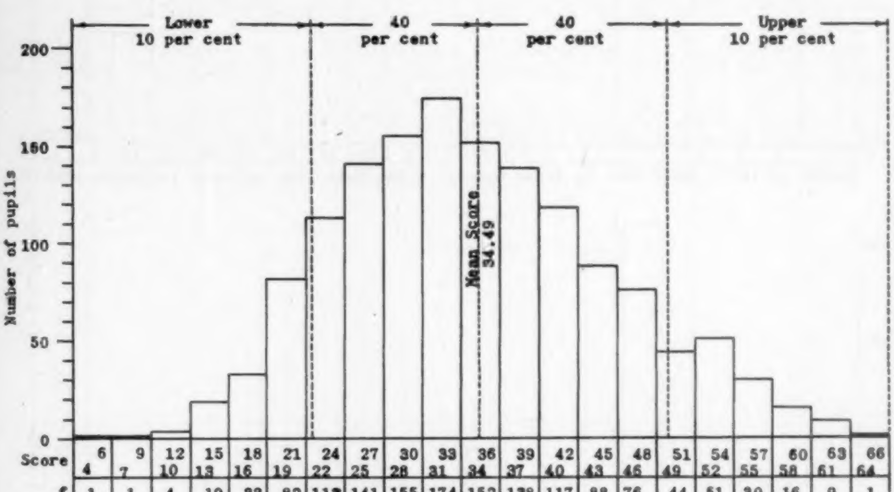
1. Lower ten per cent in science were about 31, 48, 41, and 45 per cents respectively.

TABLE VII

NUMBERS OF SENIORS WHOSE SCORES IN MATHEMATICS, SOCIAL STUDIES, ENGLISH, AND INTELLIGENCE PLACED THEM IN THE UPPER TEN PER CENTS OF THOSE DISTRIBUTIONS DISTRIBUTED AS SHOWN ON THE BASIS OF THEIR SCIENCE SCORES INTO THE RANGES INDICATED

	Mathematics		Social Studies		English		Intelligence	
Ranges of Science Scores *	N	%	N	%	N	%	N	%
Lower 10 per cent Range of Scores: 5 to 22	1	0.69	..	.....	1	0.69	2	1.38
40 per cent below the mean Range of Scores: 22 to 34.49	8	5.52	5	3.45	9	6.21	5	3.45
40 per cent above the mean Range of Scores: 34.49 to 49	77	53.10	64	44.14	87	60.00	62	42.76
Upper 10 per cent Range of Scores: 49 to 65	59	40.69	76	52.41	48	33.10	76	52.41
Totals	145	100.00	145	100.00	145	100.00	145	100.00

* Based on the total distribution of science scores for the 1,445 seniors.



A histogram of SCIENCE ACHIEVEMENT scores resulting from a test taken by 1445 graduating high school seniors in Kansas.

FIGURE 1.

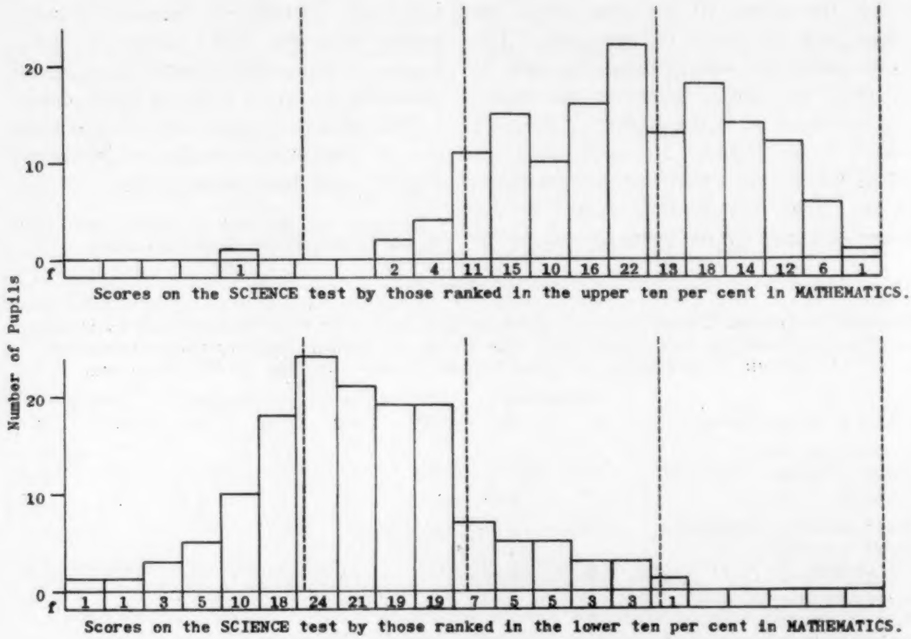


FIGURE 2.

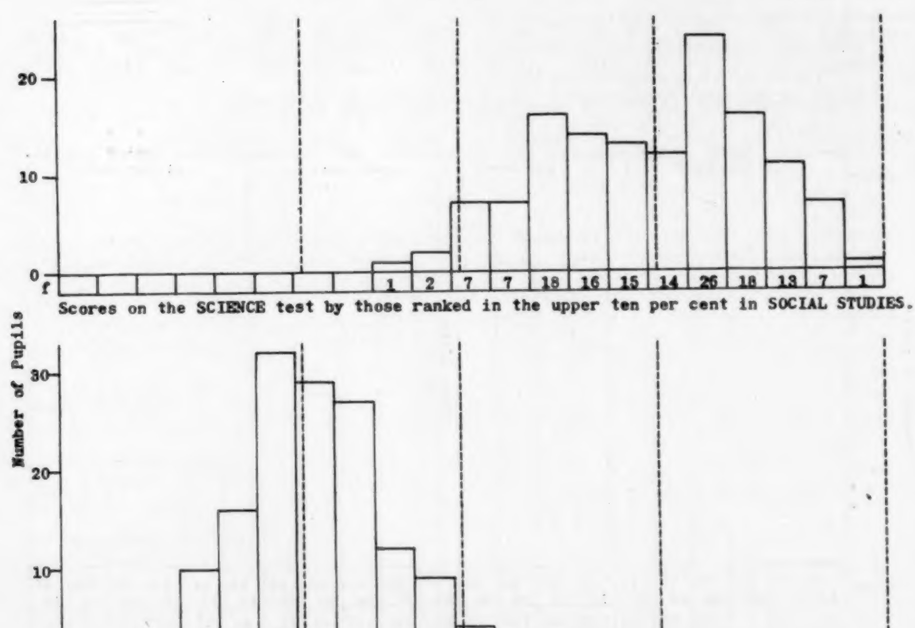


FIGURE 3.

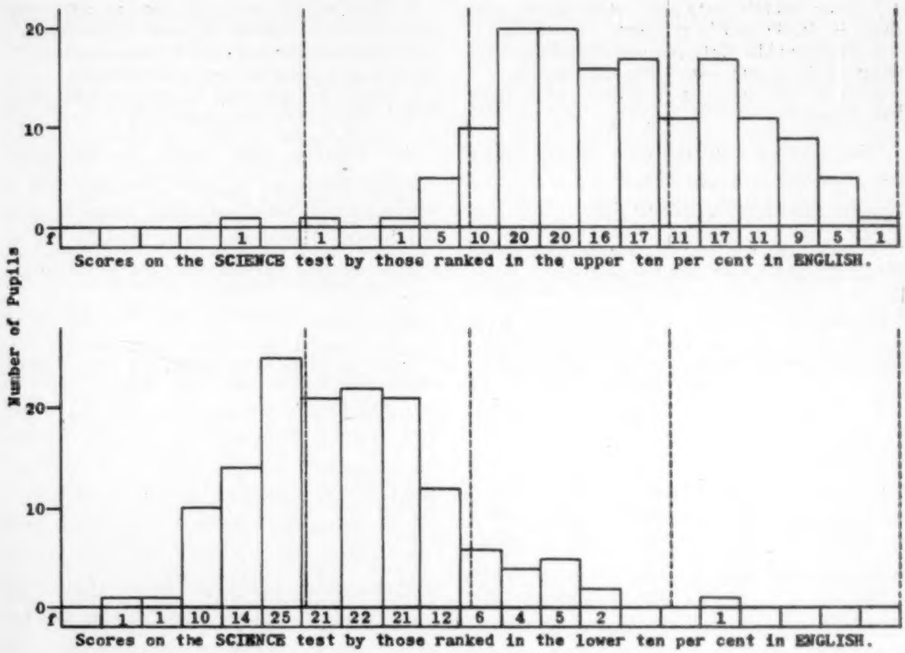


FIGURE 4.

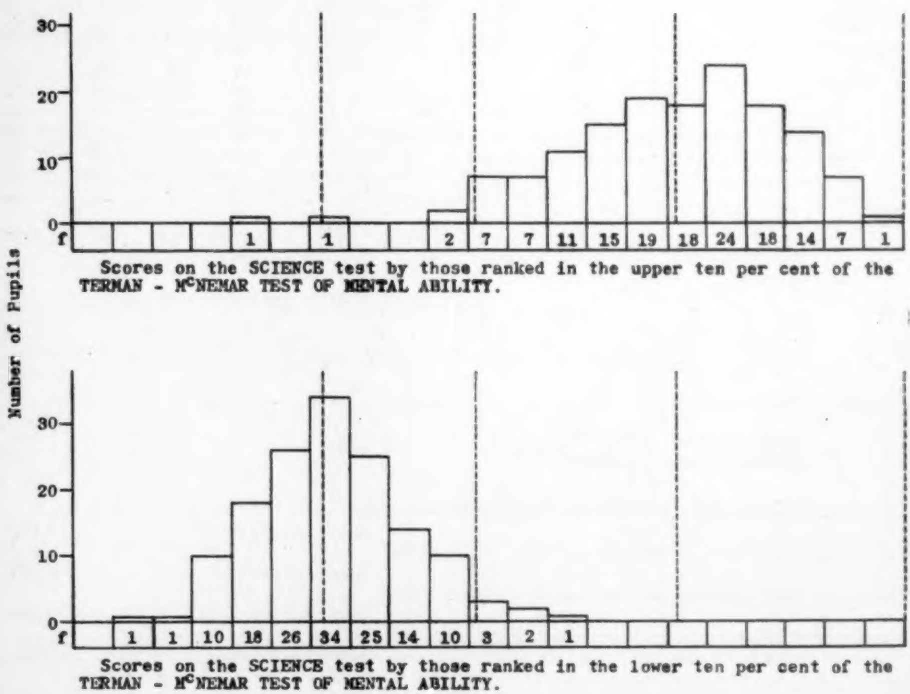


FIGURE 5.

2. Lower-middle forty per cent in science were about 54, 48, 49, and 52 per cents respectively.
3. Upper-middle forty per cent in science were about 14, 4, 10, and 3 per cents respectively.
4. Upper ten per cent in science were about 1, 0, 1, and 0.

The relative contributions of the upper ten per cents in mathematics, social studies, English, and intelligence to the:

1. Upper ten per cent in science were about 41, 52, 33, and 52 per cents respectively.
2. Upper-middle forty per cent in science were about 53, 44, 60, and 43 per cents respectively.
3. Lower-middle forty per cent in science were about 6, 3, 6, and 3 per cents respectively.
4. Lower ten per cent in science were about 1, 0, 1, and 1 per cents respectively.

An analysis was made to determine whether the lower or upper ten per cents in mathematics, social studies, English, and intelligence, were the most variable as to science scores. What were the percentages

TABLE VIII

DISTRIBUTIONS OF SCORES ON THE SCIENCE TEST BY THOSE WHOSE TEST SCORES ON THE MATHEMATICS TEST PLACED THEM IN THE UPPER AND LOWER TEN PER CENT

	Upper Ten Per Cent					Lower Ten Per Cent				
Class Interval	F	CF	x	Fx	Fx²	F	CF	x	Fx	Fx²
64–66	1	145	6	6	36					
61–63	6	144	5	30	150					
58–60	12	138	4	48	192					
55–57	14	126	3	42	126					
52–54	18	112	2	36	72					
49–51	13	94	1	13	13	1	145	8	8	64
46–48	22	81				3	144	7	21	147
43–45	16	59	—1	—16	16	3	141	6	18	108
40–42	10	43	—2	—20	40	5	138	5	25	125
37–39	15	33	—3	—45	135	5	133	4	20	80
34–36	11	18	—4	—44	176	7	128	3	21	63
31–33	4	7	—5	—20	100	19	121	2	38	76
28–30	2	3	—6	—12	72	19	102	1	19	19
25–27		1	—7			21	83			
22–24		1	—8			24	62	—1	—24	24
19–21		1	—9			18	38	—2	—36	72
16–18	1	1	—10	—10	100	10	20	—3	—30	90
13–15						5	10	—4	—20	80
10–12						3	5	—5	—15	75
7–9						1	2	—6	—6	36
4–6						1	1	—7	—7	49
	145			8	1228	145			32	1108

$$\overline{X} = 47 + \frac{8}{145} \times 3 = 47.17 \qquad \overline{X} = 26 + \frac{32}{145} \times 3 = 26.66$$

$$\text{S. D.} = 3\sqrt{\frac{1228}{145} - \frac{(8)^2}{(145)^2}} = 8.73 \qquad \text{S. D.} = 3\sqrt{\frac{1108}{145} - \frac{(32)^2}{(145)^2}} = 8.28$$

$$\text{Variance} = (8.73)^2 = 76.2129 \qquad \text{Variance} = (8.28)^2 = 68.5584$$

$$F = \frac{\text{larger variance}}{\text{smaller variance}} = \frac{76.2129}{68.5584} = 1.11 \qquad P > .10$$

Percentage of the lower ten per cent exceeding the Median of the upper ten per cent	1.49%
Percentage of the lower ten per cent exceeding the P_{25} of the upper ten per cent	7.15%
Percentage of the lower ten per cent exceeding the P_{10} of the upper ten per cent	13.26%
Percentage of the lower ten per cent exceeding the lowest score of the upper ten per cent	93.10%

of overlap of the lower group of the upper group in science achievement for these four other areas? Answers to these questions appear in Table IX. The results in Table IX are based on calculations similar to those which appear in Table VIII.

The upper and lower groups in mathematics and English were apparently equally variable as to science test scores, whereas the upper groups in social studies and intelligence were more variable as to science test scores than were the lower groups. The greatest amount of overlap of the lower group of the upper group in science test scores occurred in mathematics where 1.49 per cent, 7.15 per cent, and 13.26 per cent of the lower group exceeded the median, 25th percentile, and 10th percentile of the upper group respectively. An even greater percentage of overlap was expected here but the lack of questions in the science test stressing quantitative relationships probably accounts for the low percentage of overlap. The least amount of overlap in science test scores occurred for intelligence.

Distributions of Mathematics Scores, Social Studies Scores, English Scores, and Intelligence Test Scores of Seniors Whose Scores in Science Placed Them in the Lower and Upper Ten Per Cents of That Distribution

Seniors whose science scores placed them in the lower or upper ten per cent of that distribution were distributed as to scores in mathematics, social studies, English, and intelligence. Each score obtained was tallied into one of four categories based on the total distributions of scores for mathematics, social studies, English, and intelligence. The categories or ranges of scores for these four areas included the lower ten per cent, 40 per cent below the mean, 40 per cent above the mean, and the upper ten per cent. The exact ranges of scores for the four areas may be ascertained from Table I.

Tables X and XI and Figures 6–9 reveal that not all of the students from the lower and upper ten per cents in science distributed themselves into the lower and upper ten per cents of the other four areas

TABLE IX

STATISTICS CALCULATED FROM THE DISTRIBUTIONS OF SCORES ON THE SCIENCE TEST BY THOSE WHOSE TEST SCORES ON THE MATHEMATICS TEST, ENGLISH TEST, SOCIAL STUDIES TEST, AND INTELLIGENCE TEST PLACED THEM IN THE UPPER OR LOWER TEN PER CENT OF THOSE DISTRIBUTIONS

	Mathematics		English		Social Studies		Intelligence	
	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower
Mean	47.17	26.66	45.76	25.19	48.99	23.35	49.13	23.21
S.D.	8.73	8.28	8.70	7.65	7.83	5.97	8.22	5.76
Variance	76.21	68.56	75.69	58.52	61.31	35.64	67.57	33.18
F Ratio	1.11 $P > .10$		1.29 $P > .10$		1.72 $P < .02$		2.04 $P < .02$	
Median	47.34	26.00	45.22	24.57	49.89	23.72	50.08	22.96
P_{25}	40.48		39.24		42.73		43.95	
P_{10}	35.55		35.45		38.43		38.00	
Percentage of the Lower Group Exceeding the Statistic of the Upper Group								
Median		1.49		0.80		0.00		0.00
P_{25}		7.15		5.76		1.28		0.00
P_{10}		13.26		9.72		2.32		1.38
Lowest Score	(16) *	93.10	(16) *	91.71	(28) *	20.00	(16) *	91.72

* Lowest Score

tested. In fact, they distributed themselves rather widely over the entire range of scores for those examinations.

The relative contribution of the lower ten per cent in science to the:

1. Lower ten per cents in mathematics, social studies, English, and intelligence were about 16, 41, 40, and 41 per cents respectively.

2. Lower-middle 40 per cents in mathematics, social studies, English, and intelligence were about 76, 52, 49, and 50 per cents respectively.

3. Upper-middle 40 per cents in mathematics,

TABLE X

NUMBERS OF SENIORS WHOSE SCIENCE SCORES PLACED THEM IN THE LOWER TEN PER CENT OF THAT DISTRIBUTION DISTRIBUTED AS SHOWN ON THE BASIS OF THEIR SCORES IN MATHEMATICS, SOCIAL STUDIES, ENGLISH, AND INTELLIGENCE

	Mathematics		Social Studies		English		Intelligence	
Ranges of Scores *	N	%	N	%	N	%	N	%
Lower 10 per cent	23	15.86	59	40.69	58	40.00	59	40.69
40 per cent below the mean	110	75.87	76	52.41	71	48.97	73	50.34
40 per cent above the mean	11	7.58	10	6.90	15	10.34	12	8.28
Upper 10 per cent	1	0.69			1	0.69	1	0.69
Totals	145	100.00	145	100.00	145	100.00	145	100.00

* Based on the total distributions for mathematics, social studies, English, and intelligence for the 1,445 students.

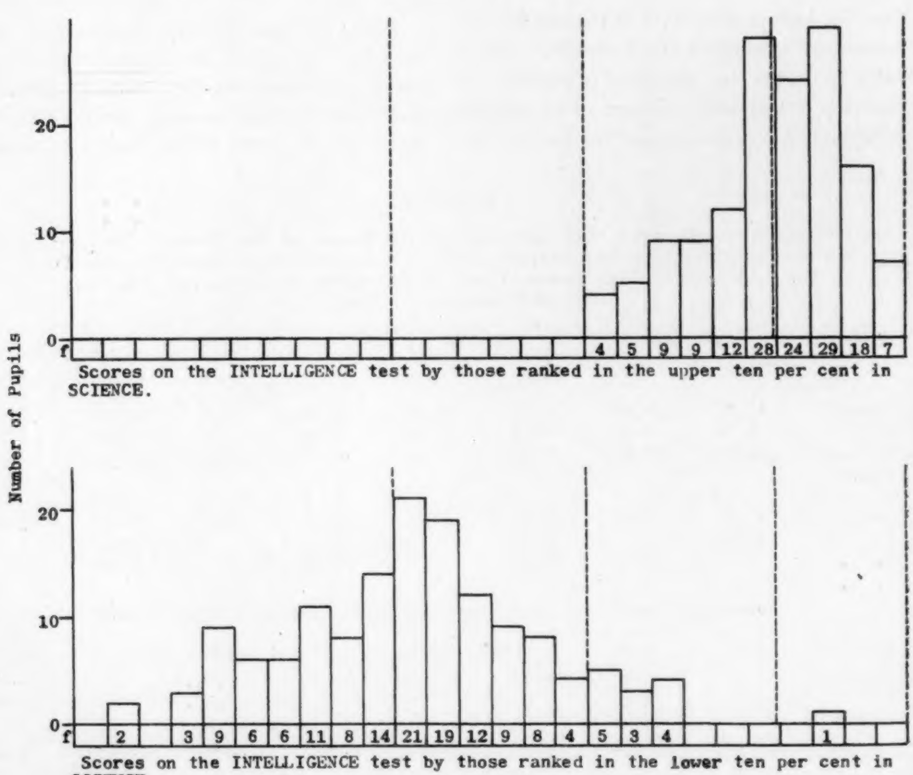


FIGURE 6.

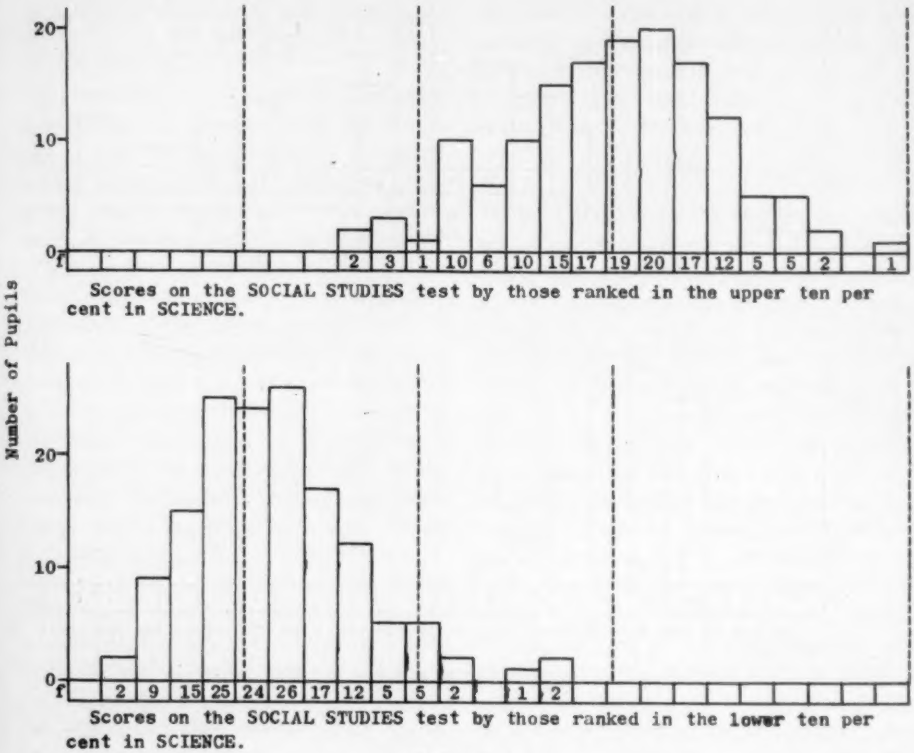


FIGURE 7.

TABLE XI

NUMBERS OF SENIORS WHOSE SCIENCE SCORES PLACED THEM IN THE UPPER TEN PER CENT OF THAT DISTRIBUTION DISTRIBUTED AS SHOWN ON THE BASIS OF THEIR SCORES IN MATHEMATICS, SOCIAL STUDIES, ENGLISH, AND INTELLIGENCE

	Mathematics		Social Studies		English		Intelligence	
Ranges of Scores *	N	%	N	%	N	%	N	%
Lower 10 per cent	1	0.69			1	0.69		
40 per cent below the mean	14	9.66	5	3.45	6	4.14		
40 per cent above the mean	67	46.21	59	40.69	80	55.17	63	43.45
Upper 10 per cent	63	43.44	81	55.86	58	40.00	82	56.55
Totals	145	100.00	145	100.00	145	100.00	145	100.00

* Based on the total distributions for mathematics, social studies, English, and intelligence for the 1,445 students.

social studies, English, and intelligence were about 8, 7, 10, and 8 per cents respectively.

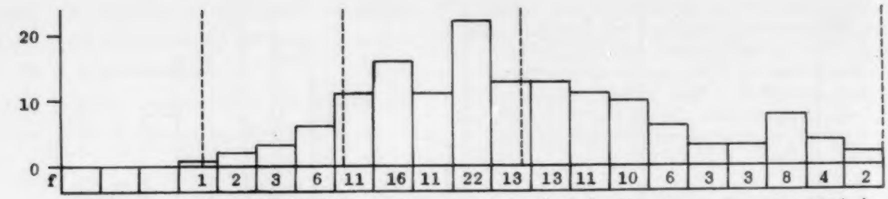
4. Upper ten per cents in mathematics, social studies, English, and intelligence were about 1, 0, 1, and 1 per cents respectively.

The relative contribution of the upper ten per cent in science to the:

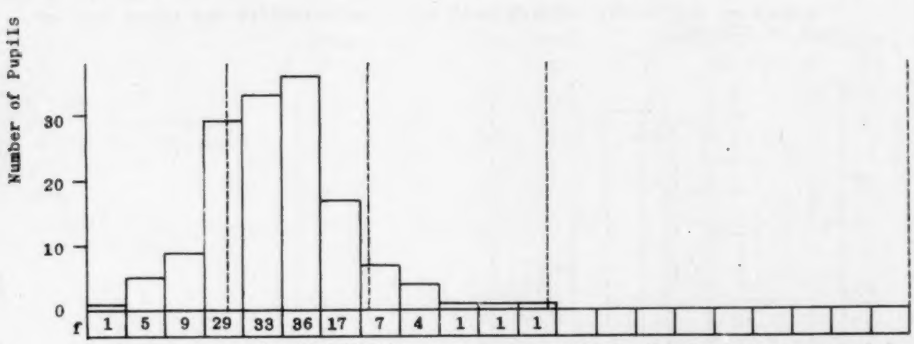
1. Upper ten per cents in mathematics, social studies, English, and intelligence were about 43, 56, 40, and 57 per cents respectively.

2. Upper-middle 40 per cents in mathematics, social studies, English, and intelligence were about 46, 41, 55, and 43 per cents respectively.

3. Lower-middle 40 per cents in mathematics, social studies, English, and intelligence were about 10, 3, 4, and 0 per cents respectively.

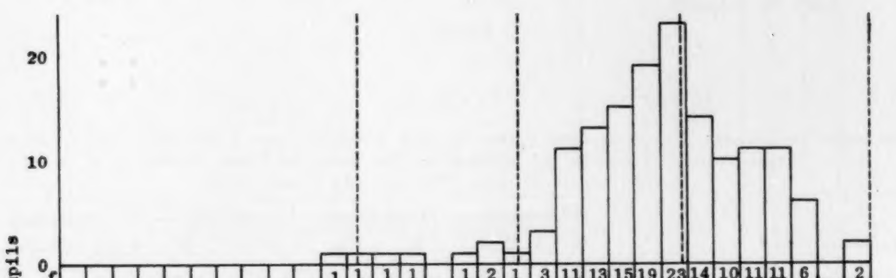


Scores on the MATHEMATICS test by those ranked in the upper ten per cent in SCIENCE.

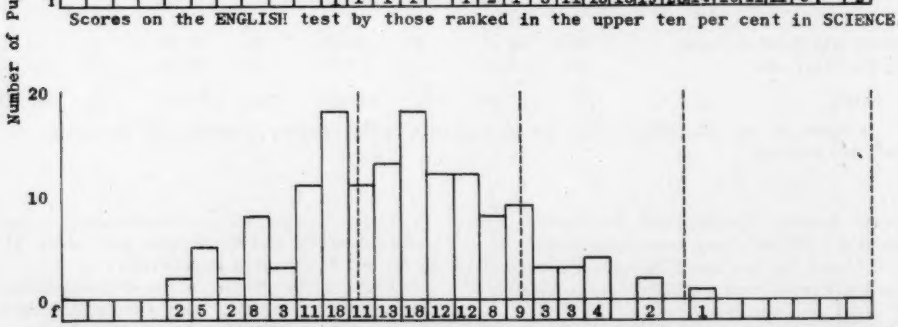


Scores on the MATHEMATICS test by those ranked in the lower ten per cent in SCIENCE.

FIGURE 8.



Scores on the ENGLISH test by those ranked in the upper ten per cent in SCIENCE.



Scores on the ENGLISH test by those ranked in the lower ten per cent in SCIENCE.

FIGURE 9.

4. Lower ten per cents in mathematics, social studies, English, and intelligence were about 1, 0, 1, and 0 per cents respectively.

An analysis was made to determine whether the lower or upper ten per cent in science was the most variable in mathematics, social studies, English, and intelligence. What was the percentage of overlap of the lower group of the upper group in achievement or ability in these four areas? Answers to the question appear in Table XII. The upper ten per cent in science was more variable than the lower group in mathematics test scores and social studies test scores, whereas the lower group was more variable than the upper group in mental ability as measured by the intelligence test. Apparently the upper and lower groups were equally variable with respect to English test scores.

The greatest amount of overlap of the lower group of the upper group occurred in mathematics, where 0.46 per cent, 2.54 per cent, and 8.56 per cent of the lower group exceeded the median, 25th percentile, and 10th percentile of the upper group respectively. Again, an even greater percentage of overlap was expected here but the lack of questions in the science test stressing quantitative relationships probably accounts for the low percentage of overlap. The least amount of overlap occurred in intelligence test scores.

SUMMARY AND CONCLUSION

The variability of exceptional high school seniors in science and other academic areas was studied through five different approaches, namely: (1) the relative contribution of the sexes to the exceptional groups, (2) the relative contribution of schools of varying size to the exceptional groups, (3) the correlation of achievement in science with achievement or ability in the other four areas tested, (4) the variability in science achievement by the exceptional groups in the other four academic areas, and (5) the variability in achievement in the other four academic areas of the exceptional groups in science.

For purposes of this study, a senior was designated as exceptional if his score on a particular test placed him in the upper or lower ten per cent of the frequency distribution for that test. The exceptional groups were chosen from a representative

TABLE XII

Statistics Calculated from the Distributions of Scores on Mathematics, Social Studies, English, and Intelligence by Those Whose Science Test Scores Placed Them in the Upper or Lower Ten Per Cent of that Distribution

	Mathematics		Social Studies		English		Intelligence	
	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower
Mean	37.46	17.32	59.19	28.84	200.00	149.41	139.31	71.83
S.D.	11.25	5.28	9.15	7.26	16.95	18.55	10.90	18.50
Variance	126.56	27.88	83.72	52.71	287.30	344.10	118.81	342.25
F Ratio	4.54 $P < .02$		1.59 $P < .02$		1.20 $P > .10$		2.88 $P < .02$	
Median	35.60	17.01	59.84	28.19	200.48	149.31	140.65	82.71
P_{25}	28.98		53.35		190.25		133.35	
P_{10}	24.18		46.05		181.55		122.56	
Percentage of the Lower Group Exceeding the Statistic of the Upper Group								
Median		0.46		0.00		0.70		0.00
P_{25}		2.54		0.01		1.97		0.00
P_{10}		8.56		2.28		6.05		1.76
Lowest Score	(12) *	84.83	(35) *	28.19	(135) *	78.62	(110) *	8.97

* Lowest Score

sample of 1,445 Kansas high school seniors.

It must be remembered that this was a study of the variability in achievement of seniors with respect to science and intelligence and the academic areas of mathematics, social studies, and English. The study did not consider the effects of differing amounts of instruction in the various areas. These differences would no doubt be more evident in science and mathematics than in social studies and English where there is less election of courses. It is interesting to note in this connection that if the mean raw scores of the 1,445 seniors on mathematics and science are converted to mean standard scores on the *Essential High School Content Battery,* the scores correspond to the group which had about 4.5 semesters of science and mathematics.[1] Furthermore by the same process, the mean science standard scores of those in the upper ten per cents of mathematics, English, social studies, and intelligence correspond to the group which had 9 plus semesters of instruction in science. The mean standards scores in science of those in the lower ten per cents of mathematics, English, social studies, and intelligence correspond to those groups which had about 1.33, 0.66, 0.33, and 0.33 semesters of instruction in science respectively. One might question the validity of the examinations used for the purpose of this study. However, the purpose of the study was simply to assay the amount of variability in science achievement and other academic areas of the exceptional products of our high schools without regard to previous work in these areas. In terms of this purpose, it seems that the tests are valid.

It is evident from the findings of this study, that in spite of almost equal numbers of males and females in the original sample of 1,445 seniors, that the upper ten per cent group in science contained a significantly greater percentage of males than females, namely 67.6 per cent males as contrasted to 32.4 per cent females. The same differences were noted for mathematics and social studies, but the reverse was true in the case of English where there was a significantly greater percentage of females. In terms of the lower ten per cents, a significantly greater percentage of females than males was found in mathematics and a significantly greater percentage of males than females was found in English. The percentages of males and females in the upper and lower ten per cents in intelligence were about the same.

Apparently, size of school was not a factor in science achievement for the exceptional groups. The same was true for the exceptional groups in mathematics and for the upper groups in English and intelligence. However, in the cases of the exceptional groups in social studies and the lower groups in English and intelligence, size of school was probably a factor in achievement or ability as measured. At least the evidence in this study would seem to indicate that low achievement in the social studies was probably negatively related to size of school and high achievement in the social studies was probably positively related to size of school. Low achievement in English and low mental ability were probably negatively related to size of school.

The findings of the study revealed that the seniors in the upper ten per cent in science achievement tended to be more consistent with respect to achievement in the other areas tested than did the lower ten per cent group. The correlations of the scores in the other exceptional groups for mathematics, social studies, and English with science, revealed that the upper groups were more consistent in science achievement than the lower groups. The only exception was in the case of intelligence where both correlations were significant and positive and not significantly different. A possible explanation for the lower correlations for the lower groups

[1] *Manual of Directions, Essential High School Content Battery.* World Book Company, Yonkers-on-Hudson, New York, 1951, p. 14.

may be due to the chance responses of these students to the test items in the various tests. Perhaps one of the most surprising features of the results obtained was found in the relative small overlap between mathematics and science. To some extent this is no doubt a function of the test which tends to emphasize the non-quantitative measures in science. Nonetheless, one might well have expected to find a considerably greater percentage of overlap.

This study revealed that the distributions of science scores for the lower groups in mathematics, English, social studies, and intelligence overlapped to some extent the distributions of science scores for the upper groups from these areas. In two instances, namely mathematics and English, one senior in each achieved enough to place in the upper ten per cent in science achievement. In two instances the variability with respect to science achievement differed in that the upper groups in social studies and intelligence were more variable with respect to science achievement than the lower groups.

Considered from another point of view, the distributions of scores in mathematics, social studies, English, and intelligence for the lower group in science achievement overlapped the upper groups to some extent. In three instances, namely in mathematics, English, and intelligence, at least one senior from the lower group in science achieved enough to be placed in the upper ten per cent groups of those distributions. The upper group in science was more variable than the lower group with respect to achievement in mathematics and social studies. The reverse was true in the case of intelligence.

If one considers the average age of seniors at the time they took these tests to be about seventeen, the lower group in intelligence had deviation IQ's ranging from about 63 to 89 and the upper group had deviation IQ's ranging from about 120 to 143. In spite of this, 52.41 per cent of the lower group achieved enough in science to place them in the lower-middle 40 per cent in science achievement and 2.76 per cent achieved enough to place them in the upper-middle 40 per cent in science achievement. Also, 42.76 per cent of the upper group achieved sufficiently low enough in science to place them in the upper-middle 40 per cent in science achievement. Five seniors, or 3.45 per cent, placed in the lower-middle 40 per cent in science achievement and 2 seniors, or 1.38 per cent, placed in the lower ten per cent in science achievement. The same comparisons for the other areas revealed slightly less variation for social studies but some more variation for mathematics and English. These findings suggest that an acceptable criterion for exceptional performance in science and other academic areas must be sought outside of the province of intelligence. Apparently there are forces other than intelligence at work leading to exceptional achievement in science and other areas, such as motivation, originality, and creativity.

The specific findings of the study point up more clearly than ever the phenomenon of individual differences in science achievement and in other academic areas, as well as the great variability within individuals. In a sense, the information contained in this study documents to a considerable extent present statements of the kind of education essential in a democracy. The broadly stated purposes of education have emphasized the uniqueness of each individual and the necessity to provide for the fullest development of the unique potentialities of every individual. The analysis presented in this report is taken as further evidence that these ideals are soundly conceived.

ORIGIN OF THE CELL PRINCIPLE: AN EXAMPLE OF THE GROWTH OF SCIENTIFIC KNOWLEDGE * † ‡

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HISTORY OF SCIENCE AND SCIENTIFIC METHOD

As the title of this paper implies, I shall discuss my topic from the standpoint of both scientist and historian. As a teacher of natural science in a general education program I am concerned that my students develop some genuine understanding of science. Such understanding, I believe, must arise from a knowledge of the *results* of scientific inquiry, the *methods* whereby this inquiry is conducted, and the *impact* of these results and methods on human society. My interest in the history of science stems from the conviction that there is no better way for non-scientists to develop insights into the methods and impact of science than by careful analysis of the classical documents of scientific literature and a study of the intellectual and social context in which these documents are rooted.

I must of course confess that my interests and approach are in no sense original. Many of my colleagues at Michigan State and elsewhere have been thinking along these lines. Of particular importance in the alerting of science educators to the instructional potentialities of historical materials has been the Harvard Report. The authors of this Report urge that we attempt

> to teach science as part of the total intellectual and historical process, of which, in fact, it has always been an important part. The student should thereby gain an insight into the principles of science.[1]

That such instruction is a legitimate aspect of general education is set forth elsewhere in the Report, as follows:

> The claim of General Education is that the history of science is part of science. So are its philosophy, its great literature, and its social and intellectual context. The contribution of science instruction to the life of the university and to society should include those elements, since science includes them.[2]

Conant,[3] Cohen and Watson,[4] Gabriel and Fogel,[5] and T. S. Hall,[6] are among the many who have advocated a critical examination of the historical documents of science as part of the instructional program in introductory science at the college or university level. In the most recent edition of our textbook and laboratory manual the natural science faculty at Michigan State[7] have undertaken, as one instructional technique, an inquiry into the historical background of certain of the major concepts of modern science. Such a venture has appealed to us as having certain unique advantages for the teaching of scientific method, or what Conant has so felicitously termed "the tactics and strategy of science." My particular contribution to this inquiry

* Paper presented at the Twenty-Ninth Annual Meeting of the National Association for Research in Science Teaching, Hotel Sherman, Chicago, Illinois, April 21, 1956.

† Contribution No. 81, from the Department of Natural Science, Michigan State University, East Lansing.

‡ Investigation made possible by grants from Michigan State University and the Ford Foundation.

1 *General Education in a Free Society: Report of the Harvard Committee* (Cambridge: Harvard University Press, 1945), p. 277.

2 *Ibid.*, p. 222.

3 *On Understanding Science* (New York: New American Library, 1951).

4 *General Education in Science* (Cambridge: Harvard University Press, 1952).

5 *Great Experiments in Biology* (Englewood Cliffs, N. J.: Prentice-Hall, 1955).

6 *Source Book in Animal Biology* (New York: McGraw-Hill, 1951), and personal communication.

7 See *Natural Science*, vols. 1 and 2, ed. C. A. Lawson (East Lansing: Michigan State University Press, 1955), also *Studies in Natural Science*, vol. 2, ed. C. A. Lawson and A. Novak (East Lansing: Michigan State College Press, 1953).

appears in the text as Chapter 5, and is entitled "The Historical Origin of the Modern Concept of the Cell."[8] In the remainder of this paper I intend to discuss the premises on which the chapter as a whole is based, to review a few of the facts and concepts presented therein, and to point to certain ways in which such materials illuminate the process whereby scientific knowledge grows.

HOW DID THE CELL PRINCIPLE ORIGINATE? A HYPOTHESIS

For the purposes of a general education science course I would be ill-advised to undertake any rigorous examination of the history of the Cell Principle. Of the many such reviews appearing in the biological literature ever since the 1840's, the latest and most exhaustive is that of Baker.[9] Those wishing to explore in detail any particular aspect of the history of the Cell Principle will find in Baker's work the indispensable point of departure. My purposes are better served by a careful study of excerpts from the writings of but a few of the more prominent pioneers. From such a study it should be possible to draw certain conclusions as to factors that influence the growth of new concepts and the discovery of new facts, at least in the more empirical realms of science.

According to the usual textbook presentation, the Cell Principle, which many prefer to call the Cell *Theory,* is perhaps the classic example of an inductive generalization. Now so long as one limits himself to the facts of modern biology he can find conclusive support for this position. The facts we now know about cells *do* stand in inductive relationship to the Cell Principle.

In further support of this idea many of us can cite our own experiences as students. We examined specimens and diagrams of various types of cells, in each of which we could discern certain common features: nucleus, cytoplasm, chromatin, and so forth. We proceeded inductively from a verification of individual facts to a gradual acceptance of the various generalizations embodied in the Cell Principle. It is not surprising, therefore, that many of us, lacking either the time or inclination to explore the historical record for ourselves, have assumed that our modern concept of the cell must have evolved in substantially the same way. We have been tempted further to assume that if such a pattern is at all typical, then by a further diligent accumulation of factual data ever wider and more significant generalizations will inevitably follow. Related to this is the assumption that scientific facts are recognized only by a mind free of prejudice or bias, and without any advance expectations of what the facts are likely to be.

I am by no means prepared to assess the degree of truth or error in any of the above assumptions. From what I know of the history of the Cell Principle, however, I strongly suspect that the actual chronology of events is rarely as simple or direct as either logic or our personal experience might suggest. I am convinced, moreover, that the picture of the dispassionate scientist with mind uncluttered by preconceptions bears little resemblance to any of the pioneer biologists whose works I have examined. On the contrary I believe there is a great deal of historical evidence to support the hypothesis that

> the facts of science, whether they concern cells or atoms or galaxies, have never been, and never will be recognized unless the would-be fact finder has some system of concepts or theories with which to evaluate the data he perceives.[10]

The very capacity to ascertain what the facts *are,* I submit, implies an interlocking system of principles or laws or hypotheses

[8] Lawson, *op. cit.,* vol. 1, pp. 38–56.

[9] John R. Baker, "The cell-theory: a restatement, history, and critique," *Quarterly Journal of Microscopical Science,* vol. 96 (1955), pp. 449–481, 14 figs. This particular paper is part 5, of a series which will eventually run to seven or eight parts. Parts 1 to 4 are published in earlier issues of the QJMS, and are cited in the list of references which Baker includes at the end of part 5.

[10] Lawson, *op. cit.,* vol. 1, p. 39

or concepts in the mind of the observer. From such a mental apparatus certain deductions are possible while others are not. When a scientist observes nature he is in effect testing some specific consequence (or deduction) from his own particular set of concepts. Now since concepts vary, both among individual scientists and from one historical period to the next, it follows that two or more scientists, confronted with identical sensory data, will not necessarily interpret these data in the same way. Indeed they may actually derive from them different sets of facts.

In my earlier account of the origin of the cell concept,[11] I have sought by rather extended analysis of excerpts from the writings of Robert Hooke and Antoni van Leeuwenhoek, together with cursory reference to the works of Robert Brown, M. J. Schleiden, and Theodor Schwann, to develop some of the evidence which I think supports the propositions in the previous paragraph. Let me now give you a few specific examples of this evidence.

HOOKE'S CONCEPT OF THE CELL

Most authorities agree that our modern knowledge of cells as biological units begins with Robert Hooke.[12] To this versatile English scientist we are indebted not only for the first published account of cells, but also for the first use of the word *cell* in reference to the microscopic structure of organisms. In a famous passage describing the cells of cork [13] Hooke speaks of "frothy bodies" such as cork, which are "perforated and porous, much like a Honey-comb"; to the fact that

> the substance of Cork is altogether fill'd with Air, and that that Air is perfectly enclosed in little Boxes or Cells distinct from one another;

and to the relatively small amount of "solid substance" of a cork specimen "in comparison of the empty cavity that was contained between." Note the emphasis here on space enclosed by substance. Elsewhere in the *Micrographia,* to be sure, we read that in living plants of several different kinds the cells are "fill'd with juices, and by degrees sweating them out." [14] These words, from their context, almost certainly refer to plant cell protoplasm, at least in part. Nevertheless it is obvious that Hooke's comments on the subject are entirely casual, and that to him the essential feature of the plant cell is the cell wall and space, and not the material it happens to enclose. From the modern viewpoint such an interpretation is the exact opposite of the proper one. And yet if we consider the various connotations of the word *cell* in Hooke's day, we will grant that his preoccupation with wall and space, and his consequent failure to recognize the importance of cell *contents,* were entirely reasonable and proper. This word, according to the Oxford English Dictionary, takes its origin from the Latin, *cella,* which means

> a small apartment, esp. one of several such in the same building, used e.g., for a store-closet, slave's room, prison cell; also cell of a honeycomb; in late L. also a monk's or hermit's cell.[15]

Since its first adoption from the Latin it has acquired at least fifteen different meanings, or senses,[15] of which eight had appeared in various English writings prior to the time of Hooke. Each of these implies space or enclosure, whether in reference to honeycombs, monasteries, small rooms, or cavities or compartments in a more generalized sense. The essence of cellularity to a 17th century Englishman, in other words, was space delimited by some sort of boundary substance. Since slices of dried cork viewed microscopically show some resemblance to a honeycomb, the justification for Hooke's analogy is clear, as is also his reason for choosing this particular word to symbolize his concept.

[11] Lawson, *op. cit.*, Vol. 1, Chap. 5.
[12] See *Micrographia* (London, 1665). For a synopsis of the contents of this work, together with photostatic copies of representative passages, consult L. L. Woodruff, *American Naturalist,* vol. 53 (1919), pp. 247–264.
[13] Woodruff, *op. cit.*, p. 252.
[14] Woodruff, *op. cit.*, p. 253.
[15] Vol. 2 (1893), pp. 212–213.

From this concept he could deduce various other properties that cells in general should have, while certain properties as for instance protoplasmic contents would not be so deduced. Hence he was unable to develop a concept of the cell based on protoplasm, and thus capable of extension to all types of plant cells, and to animals as well.

It is illuminating in this connection to cite two instances where Hooke's concept proved inadequate to the occasion. Both pertain to animal material. By analogy with plant tissue, Hooke refers to feather pulp as "pith," and to each individual space therein as a "Cavern, Bubble, or Cell." [16] From the standpoint of modern histology, however,[17] the spaces in feather pulp are in*ter*- rather than in*tra*-cellular, a nicety Hooke could have discerned only with a knowledge of feather embryology and a concept of the cell as nucleated protoplasm. Again, in describing mammalian hair he compares the imbricating scales on the hair surface to

> a thread of course Canvass, that has been newly unwreath'd, it being all wav'd or bended to and fro, much after that manner.[18]

Though we know these scales to be modified epithelial cells, Hooke of course did not so name them, nor did he conceive of them as cells at all.

LEEUWENHOEK'S ACCOUNTS OF CELLS

Hooke's description of cells comprises but a small part of the *Micrographia,* and is confined to only a few species of higher plants. Leeuwenhoek's investigations, on the other hand, were both wide-ranging and sustained. He communicated his findings to his contemporaries in a series of letters covering a span of fifty years.[19] Among the cells that he was either the first to observe, or toward a knowledge of which he made important contributions, are the spermatozoa of man and other animals, blood corpuscles, bacteria (spherical, spiral, and rod-shaped types), a wide variety of protozoans, and pith cells in the stems of grasses. In my earlier article on the Cell Principle [20] I have quoted excerpts from Leeuwenhoek's letters, describing what he saw in each of these instances. Each excerpt is accompanied by a copy of Leeuwenhoek's drawing of the cells in question, together with a drawing or photograph of the same cell type as viewed by modern methods. On the basis of these materials it is clear to me that Leeuwenhoek saw and accurately recorded a large amount of empirical data about different cells. But at the same time it is equally evident that these data did *not* lead him to any unified interpretation of the structure or function of organisms. Thus, I am aware of no instance where he speaks of *cells,* not even in reference to pith. In the excerpts to which I have alluded he uses the following names for each cell type listed:

for bacteria: creatures, tubes, animalcules, little eels, worms, fibers.
for spermatozoa: animalcules.
for protozoans (genus Vorticella): animalcules.
for red blood corpuscles: oval particles, ovals of blood.
for pith cells of grasses: vessels.

I interpret such a list as evidence that Leeuwenhoek was impressed by the diversity of cells rather than by their fundamental similarity.

In the foregoing list you will note that the term *animalcules* is applied to three types of cells. So far as I am aware, this is Leeuwenhoek's closest approach to a unifying concept. From the contexts in which the word appears, it seems that an

[16] Hooke, *op. cit.,* p. 116.

[17] See Frank R. Lillie, *Physiological Zoology,* vol. 13 (1940), pp. 144 and 145, for general comments on the histology of feather pulp.

[18] Hooke, *op. cit.,* p. 158.

[19] For copies of the letters, in the original Dutch, with parallel English translation, see *The Collected Letters of Antoni van Leeuwenhoek,* edited by a Committee of Dutch Scientists, Parts 1–4 (Amsterdam: Swets and Zeitlinger, Ltd., 1939–1952). Letters 1–81, covering the period from April 28, 1673, to July 25, 1684, are included in the above parts. Other parts are in process of preparation, according to the publishers.

[20] Lawson, *op. cit.,* vol. 1, pp. 44–51.

animalcule is any organic entity of microscopic dimensions, individual existence, and spontaneous movement. With such a concept Leeuwenhoek or his successors might have devised some semblance of a generalized interpretation of the motile unicellular organisms. By the same concept, however, we would not be surprised to find him grouping certain microscopic *multi*cellular organisms such as rotifers with the bacteria and protozoans. As a matter of fact Leeuwenhoek did precisely this.[21] On the other hand, we would not expect him to classify as animalcules any non-motile cells, as for example blood corpuscles or certain bacteria. Moreover, the aggregate of stationary and closely contiguous cellular compartments of which the pith of a plant stem consists has no conformity whatever to properties deducible from an animalcule concept. That Leeuwenhoek's thinking followed along some such lines is evident from his reference to pith cells as *vessels.*

Just as Hooke, with his limited cell concept, was unaware of the significance of the "juices" in the plant cell or the "scales" on the surface of the deer hair, so in the case of Leeuwenhoek can we cite at least one observation whose significance eluded its discoverer. In the course of description of frog blood cells, which in Leeuwenhoek's vocabulary were "oval particles," we read that

> many of these oval particles . . . had a very light oval-shaped glimmer in the centre. . . .[22]

Leeuwenhoek had no inkling whatever that the *glimmer,* and the sketches accompanying this casual comment, were the first recorded observation of the nucleus of any cell.

[21] *Coll. Lett. A. v. L.,* part 2, pp. 91–92. The date of the letter in question is Oct. 9, 1676. In it Leeuwenhoek describes one particular "animalcule" which, in the opinion of the author of the annotations of this letter, is almost certainly a rotifer.

[22] *Coll. Lett. A. v. L.,* part 4, p. 73.

FORMULATION OF A GENERALIZED CELL PRINCIPLE

Students of the history of the Cell Principle are in virtual agreement that it was Brown's [23] demonstration of the widespread occurrence of the plant cell nucleus, and his realization of its probable importance, which provided the basis on which the homology of cells of the most diverse types might be established. Nuclei, as any cytologist knows, are much less prone to morphological variation than are the differentiated parts of mature cells. Hence their great importance as clues for the visual determination of what are cells and what are not. As a result of this advance, together with certain improvements in the optical properties of microscopes occurring at the same time, the 1830's witnesses a spectacular upsurge of interest in the microscopic study of living forms. Data on cell structure grew apace, and by the end of the decade Schwann [24] had succeeded in extending the cell concept to both plant and animal kingdoms. In Schwann's words, as translated by Baker,[25] the Cell Principle is stated as follows:

> A common principle of development is the basis of all organic tissues, however diverse they may be, namely cell-formation; that is to say, nature never joins the molecules together directly into a fiber, tube, etc., but always first fashions a cell or first transforms this cell, where necessary, into the different elements of structure as they occur in the adult state.

There are of course many factual details, as well as numerous intriguing problems of historical criticism related to the origin of the Cell Principle, which I am unable on this occasion to bring to your attention. One of these in particular, namely the intermediary role of M. J. Schleiden, and the

[23] Robert Brown, *Transactions of the Linnaean Society of London,* vol. 16 (1833), p. 710.

[24] Theodor Schwann, *Mikroskopische Untersuchungen über die Uebereinstimmung in der Struktur und dem Wachsthum der Thiere und Pflanzen.* (Berlin: G. E. Reimer, 1839). This volume is also available in an English translation, dated 1847.

[25] J. R. Baker, *QJMS,* vol. 89 (1948), p. 104.

origin and fate of his hypothesis of the cytoblast[26] I expect to work up and publish in the near future. Meanwhile, I trust that I have presented a sufficient sampiing of historical facts and my interpretations of them to justify a few concluding comments.

CONCLUSION

If the history of the Cell Principle is of any value in a general education program in science, it is in terms of the insights it affords into the process of scientific discovery. Scientific knowledge is cumulative. But we find little support, at least in this instance, for the proposition that accumulation is tantamount to progress, if we define progress as advance toward the level of comprehension we now enjoy. That progress will occur is one of the articles of the scientist's credo. In any given period, however, the rate of progress may differ strikingly from that in earlier or later periods.

A complete analysis of the factors determining the rate and direction of growth of scientific knowledge would be substantially a history of civilization itself. Today I have chosen to limit myself to a few specific instances in which the deductive relationships between concepts and observations are illustrated. These particular concepts enabled biologists not only to organize their knowledge about the structure of organisms but to extend that knowledge. In certain cases, however, they led these same investigators to overlook data (Leeuwenhoek's "glimmer," Hooke's "juices") which in the light of subsequent discoveries about cells have assumed positions of major importance.

To summarize, I contend that the history of the Cell Principle exemplifies certain important features of the growth of scientific knowledge in any of its ramifications. Each investigator's findings are at best tentative, and reveal the limitations of the knowledge of his time. As further data accumulate and more inclusive concepts and theories are devised, the findings of an earlier day are re-evaluated, assuming thereby their rightful status in the total structure of man's knowledge of the universe.

[26] This concept was published in 1838, in a paper entitled "Beiträge zur Phytogenesis," appearing in the *Archiv für Anatomie, Physiologie und wissenschaftliche Medicin*, Jahrg. 1838, p. 137. Schleiden himself credits Brown's observations on the nucleus as the inspiration for his hypothesis. Schwann, in turn, seized upon the cytoblast as the basis on which he might organize under a single generalized Cell Principle the data then known about plant *and* animal cells.

STUDENT DRAWINGS VS. PHOTOMICROGRAPHS *

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The student-made drawing probably is as old as the study of biology itself. Now and again we hear its use questioned on the ground that the expedient is time consuming, or that it makes little contribution to the learning process in the case of many students.

Meanwhile, photographic and microprojection techniques have been developed, and the range of available visual materials for instructional purposes is much greater than it was a generation ago.

It is therefore believed that the results of a study recently completed at Niagara University may be of general interest. These results by no means answer all questions with respect to the use of visual aids in science instruction, but they do point the way to certain general conclusions.

The process of drawing is much used as a form of laboratory procedure at the college level. The time consumed in the production of drawings reaches its maximum in microscopic work in biology, where it tends to form the major part of the laboratory procedure. Whether the making of the laboratory drawings is educationally justified or whether it is merely a traditional laboratory procedure which has little value has not been fully determined by educational research.

The subject of laboratory drawings and methodology in biology has received considerable attention in educational research. The more significant studies at the college level are those by Ayer,[1] Colton,[2] Taylor,[3] Alpern,[4] and Bergman.[5] Although many of the findings do not agree, there is a high consistency of data among the studies to indicate that the student-made drawing may well be replaced by other methods of recording biological information. But the usefulness of any particular method as a teaching procedure or a teaching aid can be determined only by carefully controlled experiments in that area of biology involved. Very little controlled research has been done on methods of teaching biology at the college level. An investigation of the contribution of photomicrographs to the field of biology has never been performed. A number of articles have been written relative to their use, but they are all based on opinion and not on carefully controlled experimentation.

The problem of the study reported here is to determine the relative values with respect to the acquisition and retention of factual knowledge of two methods of laboratory procedure: (1) Having the students make the drawings from their observations of the specimen under the microscope, and (2) having the students record their observations on photomicrographs of the specimens under the microscope.

The student-made drawings referred to in this study were of the representative

* Based on doctoral study "An Experimental Investigation of the Relative Effectiveness of Student-made Drawings and Photomicrographs in Pre-Professional Biology" completed at Teachers College, Columbia University, 1951.

[1] Fred C. Ayer, *The Psychology of Drawing with Special Reference to Laboratory Teaching.* Doctor's Thesis, Baltimore, Maryland: Warwick and York, Inc., 1916.

[2] Harold S. Colton, "Drawing a Factor in the Training of Students in a Course in General Zoology," *School and Society,* Vol. XXIV (Oct. 9, 1926), pp. 463–464.

[3] Laurene Taylor, "The Ready-Made Drawing in Relation to Student Achievement," *School and Society,* Vol. XVII (Feb. 1933), pp. 59–63.

[4] Morris Alpern, "A Study of the Effectiveness of Student-Made and Prepared Drawings in College Biology," *Science Education,* Vol. XX (Feb. 1936), pp. 24–30.

[5] George Bergman, "The Effectiveness of Charts in the Teaching of Certain Units of College Biology," *Science Education,* Vol. XXIV, (Feb. 1940), pp. 103–11.

type. They were designed to reproduce as accurately as possible the exact appearance of objects seen under the microscope. The term "photomicrographs" as used in this study refers to actual photographs of the slides under observation, or photographs of similar slides which had the essential features of the material under observation. These photomicrographs were given to the student while he was making his microscopic observations, and were labeled and described by him. "Microscopic Work in Pre-professional General Biology" refers to the microscopic work given in pre-professional courses in biology which is a fairly standard commodity in most colleges and universities.

Elementary histology is included in pre-professional college biology for a definite purpose—to help the student begin to understand the structure and functioning of living cells and tissues. This purpose demands that the student be able to recognize as many tissues as possible and that he understand the structures and functions of these tissues. The units which served as a basis for this study were: (1) epithelial tissues, (2) connective tissues, (3) muscular tissues, (4) nerve tissues, (5) blood vessels, (6) skin and kidney, (7) the alimentary canal. These units were selected because they are generally taught to pre-professional biology students and photomicrographs were available for them.

In order to arrive at a solution to the problem of evaluating the relative effectiveness of learning biology by two procedures, certain limitations were placed upon the experiment. The subject matter used for the project was pre-professional biology as taught at Niagara University, Niagara Falls, New York. This institution is a liberal arts college which had an enrollment of 1,631 students for the academic year 1950–51.

The study was limited to that part of the spring semester of the years (1949–1950) and (1950–51) in which laboratory work was concerned with histological studies. In addition, the findings of this study are limited to the extent that they are based on 161 students who were mostly college sophomores.

The experimental technique employed was that of the paired group method of measuring changes in knowledge. In conducting a study of this type it is essential that the experimental and the control groups be equated for the trait which is to be measured—ability to do microscopic work in biology. It is apparent that any such capacity will be dependent upon two factors—intelligence and experience. Keeping this in mind a list of 11 factors which influence learning performance was drawn up. They were: (1) I.Q., (2) scholastic aptitude, (3) mark on cooperative College Biology Test, (4) Mark on Histology Pretest, (5) first semester laboratory grades, (6) college average, (7) sex, (8) age, (9) college class, (10) field of interest, and (11) number of terms of biology, physics, and chemistry studied in high school. In developing a standard for the pairing of the students to be used as subjects, it was observed that similarity in at least 9 of the 11 factors could be used as a basis for judgment. After careful selection and discrimination, 110 students, or 55 pairs of students, were chosen to serve as subjects for the experiment.

The limitations as to the size of the classes were not prearranged but were based upon the actual conditions of class assignment by the scheduling authorities. The classes met for two two-hour laboratory periods per week. The laboratory procedure consisted of:

1. An introductory period in which the instructor explained the purpose of the exercise and the relationship between the microscopic slides to be examined and the biology theory.
2. The laboratory exercise proper, in which (during the major portion of the period) the students viewed microscopic slides, made observations, and used supplementary aids such as reference books, specially prepared microscopic slides, and the like.
3. Recitation and clarification of the work taken up in the laboratory.

Another characteristic of the project was the use of the same teacher for all theory sections and the same instructors for all sections of the laboratory. This eliminated the factor of individual differences in teachers and the difficulty of equating basic characteristics that are necessary for an objective solution.

A final limitation dealt with the testing program to measure learning of factual material. An examination of the objective type was devised and used as a pre-test and a post-test. Two months after the post-test the same test was again applied to measure permanent retention. The test consisted of 50 multiple choice and 50 identification questions. The characteristics which a test of this type should possess are validity, reliability, and objectivity. The validity of a test may be defined as the extent to which it measures what it presumes to measure. This test was considered to be sufficiently valid as it was in agreement with the course of study; with the materials set forth in basic college biology textbooks; and with the minimum essentials for the subject which have been established by qualified authorities.

Reliability denotes the accuracy and consistency of a test. The test used was composed of a large number of independent items. These were selected carefully from the area of histology. The range of difficulty was sufficiently wide to give full scope to the range of ability and accomplishment within the class. The reliability coefficient was found by the "split half" procedure, using the Spearman-Brown correction formula. The reliability coefficient for inter-test reliability as computed by odd-even correlation technique on 50 students selected at random from the total group was 0.82.

The third characteristic of this test was objectivity. This was assured by the form in which the test items were stated; that is, only one answer satisfied the requirements of the test item. The test was scored on the basis of a scoring key, which was prepared before the experimental testing was begun. The scoring was done by or under the direction of the writer.

The experiment involved the use of 25 student-made drawings and 25 corresponding photomicrographs. The test consisted of 100 objective questions with one score point given for each item correctly answered. In order to interpret the data and to present the results of the investigation, the gain for each student from the pre-test to the post-test was computed. The individual gains for each student were combined into two groups: Group C and Group E. Group C, the control group, contains all the gains in scores made by the students who made and labeled their own drawings of the material under observation, while Group E, the experimental group contains all the gains in scores made by the students who labeled photomicrographs of the material observed. Table I presents these data, indicating the mean gains of the two groups, the standard deviations of the gains, the sigmas of the means, the difference of the means, the coefficient of correlation and the critical ratio of Group C and Group E.

The mean gain of Group E is 70.82 score points; the mean gain of Group C is 65.64 score points; Group E exceeds Group C by 5.18 mean score points. The sigma of the difference, 5 D, is 1.85. The difference divided by the sigma of the difference gives 2.80, the critical ratio. According to Garrett,[6] a critical ratio of 2.80 indicates there are about 99 chances out of 100 that this denotes superiority and hence such a ratio would be considered significant. Therefore, the mean gain of Group E is significantly superior to that of Group C, and guarantees certainty that photomicrographs were superior to student-made drawings, and under conditions similar to those in this study, were effective

[6] H. E. Garrett, *Statistics in Psychology and Education.* New York: Longmans Green Co., 1949, p. 161.

TABLE I

ANALYSIS OF DIFFERENCES IN PERFORMANCE ON THE ACHIEVEMENT TEST ADMINISTERED TO THE CONTROL AND THE EXPERIMENTAL CLASSES AS A PRE-TEST, A POST-TEST, AND A RETENTION TEST

Achievement	Experimental Group E		Control Group C
No. of students in each group	55		55
Mean scores on Pre-test	9.98		9.75
Standard Deviation on Pre-test	2.98		2.87
Mean scores on Post-test	79.65		74.27
Standard Deviation on Post-test	10.50		11.60
Mean Achievement Gain	70.82		65.64
S.D. of Achievement Gain	11.85		11.25
S.E.M. of Achievement Gain	1.60		1.52
Difference in Means		5.18	
Coefficient of Correlation		.32	
Probable Error of Coef. of Cor.		.08	
Standard Error of Diff. in Means		1.85	
Critical Ratio		2.80	
Retention			
No. of students in each group	55		55
Mean scores on Pre-test	9.98		9.75
Standard Deviation of Pre-test	2.98		2.87
Mean scores on Retention test	64.45		57.55
S.D. on Retention Test	11.50		12.85
Mean Retention Gain	54.10		47.75
S.D. of Retention Gain	13.00		12.00
S.E.M. of Retention Gain	1.76		1.62
Difference in Means		6.35	
Coefficient of Correlation		.37	
Probable Error of Coef. of Cor.		.09	
Standard Error of Diff. in Means		1.90	
Critical Ratio		3.45	

in enabling students to make significantly higher score gains on objective tests which measure the acquisition of factual material in elementary histology.

Approximately two months after the last unit of study the same objective test that was used for achievement was re-administered to measure retention or recall. The gains between the pre-test scores and the retention test scores were computed and treated statistically in the same manner as for evaluating gains between the pre-test scores and the post-test scores. An inspection of Table I reveals that the mean score point gains in retention of Group E exceed the mean score point gains in retention of Group C by 6.35 points; the sigma of the difference is 1.90; the coefficient of correlation and its probable error are .37 and .09 respectively; and the critical ratio is 3.45. That this difference is significant is shown by the critical ratio of 3.45 which indicates virtual certainty. Thus the use of photomicrographs proved to be more effective than student-made drawings in producing higher score point gains on tests to measure retention of learning in elementary histology as taught to pre-professional college biology students.

The data recorded in Table II gives a specific analysis of the seven histology units investigated in this study. Both classes made significant gains on all parts of the achievement test during the time-sequence from the pre-test to the post-test. The specific analysis shows:

1. *Epithelium*

The experimental class showed a mean increase of 88 over the control class. With a standard error of the difference between the two means of .44, it was possible to arrive at a C. R. of 2.00 which gave a probability of 95

chances out of 100 that this was a valid difference and therefore was a sign of superiority for the photomicrographs over the student-made drawings.

2. *Connective Tissues*

The experimental group showed a slight increase on the final test in its mean score of .93 over the control group mean. The standard error of the difference between the means was .48 which gave a critical ratio of 1.94. This can be interpreted to mean that there were about 94 chances out of 100 that the difference between the means was a true difference. This probability is usually considered statistically significant.

3. *Muscular Tissues*

The mean gain for the pairs of students as shown in Table II revealed a loss of .92 for the experimental group. This means that the value of —.92 was in favor of the control class. A critical ratio of 1.88 was secured by dividing the mean gain by the standard error of difference between the means which amounted to .49. This can be interpreted to mean that the difference between the means would arise in about six cases out of 100, from errors of sampling or other factors. Such a factor is usually considered statistically significant and therefore can be regarded as a sign of superiority for the student-made drawings over the photomicrographs.

4. *Nerve Tissues*

The findings listed in Table II show that the large mean difference of 1.27 is 2.54 times the standard error of the difference, .50, and the chances are 98 out of 100 that this is real superiority and not due to chance fluctuation. The gain was made by the experimental class which had used the photomicrographs.

5. *Blood Vessels*

The large gain by the experimental class (1.08) was followed by a standard error of the difference between the means of .34. This gave a C.R. of 3.18, making the odds 99 out of 100 that this was a true increase. Therefore, it is to be regarded as statistically significant.

6. *Skin and Kidney*

The experimental class showed a mean increase of 1.25 over the control class. With a standard error of the difference between the two means of .42 it was possible to arrive at a critical ratio of 2.98 which indicated that in about 99 cases out of 100 this was a real superiority and not due to chance.

7. *Alimentary Canal*

The critical ratio was .10 since the difference between the means was .05 and the standard error was .51. The mean gain was .05 which means that the experimental group showed an increase, but there are 92 chances in 100 that the gain could have arisen from random errors in sampling.

To determine the effectiveness of the use

TABLE II

ANALYSIS OF DIFFERENCES IN PERFORMANCE ON THE ACHIEVEMENT TEST ADMINISTERED TO THE CONTROL AND THE EXPERIMENTAL CLASSES AT THE END OF THE EXPERIMENTAL PERIOD

Unit		Control Class	Exper. Class	Diff. in M.	S.E. Diff. M.	r	PE_r	C.R.
Epithelium	Mean	10.29	11.17	.88	.44	.40	.09	2.00
	S.D.	3.12	3.07					
	S.E.M.	.42	.41					
Connective Tissue	Mean	8.87	9.70	.93	.48	.33	.08	1.94
	S.D.	2.97	3.26					
	S.E.M.	.40	.43					
Muscle	Mean	10.91	9.99	—.92	.49	.35	.08	1.88
	S.D.	3.33	3.01					
	S.E.M.	.44	.41					
Nerve Tissues	Mean	8.04	9.31	1.27	.50	.30	.08	2.54
	S.D.	2.26	2.98					
	S.E.M.	.30	.40					
Blood Vessels	Mean	7.26	8.34	1.08	.34	.37	.08	3.18
	S.D.	2.28	2.29					
	S.E.M.	.31	.30					
Alimentary Canal	Mean	10.57	10.62	.05	.51	.35	.08	.10
	S.D.	3.56	3.17					
	S.E.M.	.47	.43					
Skin and Kidney	Mean	8.28	9.53	1.25	.42	.43	.09	2.98
	S.D.	3.01	2.83					
	S.E.M.	.41	.37					
Total	Mean	65.64	70.82	5.18	1.85	.32	.08	2.80
	S.D.	11.25	11.85					
	S.E.M.	1.52	1.60					

of photomicrographs on "above average" and "below average" students as measured by I.Q. examinations, the author divided the experimental and the control groups into three parts. The top 25 per cent were classed as "above average," the middle 50 per cent were classed as "average," and the low 25 per cent as "below average." Therefore, there were 14 students in each group classified as "above average" and 14 students classified as "below average."

For the "below average" group the mean score point gain for Group C was 62.86; and for Group E, 58.21. Group E exceeds Group C by 4.65 mean score points. The standard deviation of Group E is almost twice that of Group C. The mean score gain of Group C of the "below average" group was 7.43 points below the mean score gain of Group C of the entire group. The mean score gain of Group E of the "below average" group was over 7.96 score points below the mean score gain of Group E of the total group.

In the "above average" group (Table III), the mean score gain of Group C was 72.86; and for Group E, 81.08. Group E then exceeded Group C by 8.22 mean score points. The standard deviation of Group C was almost twice that of Group E. The mean of Group C of the "above average" group exceeded the total mean score by approximately 10.26 score points. To determine whether the differences of the means in the "below average" group and in the "above average" groups respectively were significant, the writer determined the critical ratio of each: they were 2.54 and 4.05 respectively. According to Garrett, a critical ratio of 2.54 indicates that the chances are 98 in 100 that the difference is real and a critical ratio of 4.05 indicates about 999 chances in 1,000 that the difference is real. It can, therefore, be concluded that for both

TABLE III

ANALYSIS OF DIFFERENCES IN PERFORMANCE ON THE ACHIEVEMENT TEST ADMINISTERED TO 14 EQUATED PAIRS OF "ABOVE AVERAGE" AND "BELOW AVERAGE" STUDENTS

		Control Class	Exper. Class	Diff. in M.	S.E. Diff. M.	r	PE_r	C.R.
"Above Average"	Mean	72.86	81.08	8.22	2.03	.18	.09	4.05
	S.D.	6.45	3.85					
	S.E.M.	1.75	1.04					
"Below Average"	Mean	58.21	62.86	4.65	1.83	.32	.08	2.54
	S.D.	5.70	13.20					
	S.E.M.	.77	1.78					
Total	Mean	65.64	70.82	5.18	1.85	.32	.08	2.80
	S.D.	11.25	11.85					
	S.E.M.	1.52	1.60					

TABLE IV

ANALYSIS OF DIFFERENCES IN PERFORMANCE ON BOTH HALVES OF THE ACHIEVEMENT TEST ADMINISTERED TO THE CONTROL AND EXPERIMENTAL CLASSES AT THE END OF THE EXPERIMENTAL PERIOD

		Control Class	Exper. Class	Diff. in M.	S.E. Diff. M.	r	PE_r	C.R.
"First Half"	Mean	34.47	36.89	2.42	1.05	.33	.08	2.30
	S.D.	6.29	7.75					
	S.E.M.	.83	1.04					
"Second Half"	Mean	29.19	32.80	3.61	.72	.37	.09	5.01
	S.D.	5.13	4.27					
	S.E.M.	.69	.58					
Total	Mean	65.64	70.82	5.18	1.85	.32	.08	2.80
	S.D.							
	S.E.M.							

the "above average" students and the "below average" students the use of photomicrographs was superior to the use of student-made drawings as shown by significantly higher gains on an objective test to measure factual knowledge in elementary histology (Table IV).

Part I of the achievement examination was a multiple choice type examination designed to measure the student's knowledge of the structure and function of the histological preparations. In considering the gains made by the control and the experimental groups on the first half of the examination, we find that the mean achievement gain of Group E exceeded the mean achievement gain of Group C by 2.42 mean score points. With a standard error of the difference between the two means of 1.05, it was possible to arrive at a critical ratio of 2.30 which gave a probability of 97 chances out of 100 that this was a valid difference, and therefore a sign of superiority for the photomicrographs over the student-made drawings in the acquisition of knowledge concerning the structure and function of elementary histological preparations.

Part II of the examination consisted of the identification of 50 structures projected on the screen with a micro-projector. On this part of the achievement test the mean achievement gain of Group E exceeded the mean achievement gain of Group C by 3.61 score points. The sigma of the difference was .72 which gave a critical ratio of 5.01. This can be interpreted to mean that there are more than 999 chances in 1,000 that the differences between the two means was a true difference.

SUMMARY

The following summary of the finding of this investigation is given in order to help the reader see clearly the results in terms of factual information learned and retained.

1. Both groups made significant gains on all parts of the achievement test during the experimental period.

2. Students learned significantly more factual information in terms of total combined results for all units by the use of photomicrographs.

3. Students retained significantly more factual information in terms of total combined results for all units by the use of photomicrographs.

4. The experimental group did significantly better than the control group on all units of the histology achievement test except the units on muscular tissue and the alimentary canal.

5. The control group did significantly better than the experimental group on the unit on muscular tissue.

6. Neither the method of the photomicrographs nor the student-made drawings showed marked superiority on the unit dealing with the alimentary canal.

7. Students of both high and low I.Q. levels learned more factual information by the use of the photomicrographs.

8. Students learned significantly more factual information on both halves of the examination (the multiple choice and the identification of structures) by the use of photomicrographs.

It is believed that various educational implications of this study will be readily apparent to science teachers, and perhaps some other teachers as well. Variable amounts of student time are devoted to the preparation of drawings or sketches of biological materials in connection with a variety of courses. This practice is not unknown at the elementary level, it has been followed in junior and senior high schools, and it is well established in the laboratory experiences associated with a number of college courses. It is even represented in many professional schools.

Of course the findings of the present study pertain to a specific situation, and we may not conclude that the same findings would be made in another situation in which student personnel, methods, and materials were similar, but different in certain respects. However, the need for fur-

ther study of some of these other learning situations does become apparent, and question is raised as to whether a time-honored procedure is as efficacious or necessary as we may have assumed.

In other words, it is entirely possible that further research might reveal that the use of photomicrographs is effective as a device in learning at various grade levels and in relationship to various so-called subjects. After all, the photomicrograph does possess one inherent advantage. It may be made of the near-perfect section of tissue, or the section which most clearly illustrates the factor principle to be learned. Anyone who has dealt with microscopic materials in bulk knows how variable quality can be, and how often the individual student must be called upon to work with sub-standard materials.

THE ROLE OF INVENTION IN SOCIETY

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The following is the description of a resource unit on the nature and social significance of invention. It represents an elaboration of the subject as previously taught by the writer in conjunction with a general education science curriculum. It is designed for use in grades 12, 13 and 14, although it might be adapted for other levels and purposes. Behind this unit lies the conviction that of all aspects of science, its social effects are among the most important for the non-scientist. Perhaps even for the specialist himself an appreciation of the impact of his work is desirable and all too frequently absent.

Certainly for the non-specialist this phase of science is more important than technical content or historical narration and at least as essential as generalized method. The content has been intentionally described in rather specific terms, for meaning is operational and generalizations do not inform. The greatest formative element in modern society is worthy of more attention than we have thus far given it.

SIGNIFICANCE

There is a tendency to regard the nature and effects of scientific discovery and invention as just another specialized subject in the educational heap. The fallacy of this attitude is easily revealed by consideration of certain facts. First, technology has revolutionized not only our mode of life but our national and world problems. Second, invention is the heart of technology and without this process there would be no modern life but only a primitive, animal existence. Invention is indeed the source and mainspring of material evolution and, through this, one of the most important factors shaping the evolution of other aspects of human existence.

Educationally considered, technology lies between the natural sciences and the social sciences, and it is perhaps for this reason that it has been treated as an outcast by both. W. F. Ogburn, one of the pioneers in this area, characterizes it as follows: "Mechanization is one of the most striking and pervasive phenomena of our times. Unfortunately its study has been neglected by the social sciences which have not sufficiently recognized that while technology itself belongs to the field of the natural sciences, its far-reaching effects on social life make it a vital subject for study by the social sciences." The natural scientists, for their part, have been too preoccupied with their specialized studies to give much heed to what these discoveries were doing to the society in which they lived.

* Further development of the course of study may be found in the writer's Ph.D. thesis completed at the University of Kansas entitled: "An Integrated Science—Social Science Course for General Education."

It is probably more important for the average student to understand the effects of science, through technology, on his life and world than it is for him to learn technical information, since he will never be a real producer in natural science but he will, during all his days, be unavoidably a consumer in the most intimate sense. And herein lies the significance of a unit of this kind. The present international competition in rocket technology serves to emphasize the importance of such a study.

ANALYSIS

The subject matter presented in this outline is synthetic or integrative in scope. It draws on facts, ideas, and attitudes from both science and social science but does not adhere to the organization of either. It follows a plan of logical development which is one of many, and not necessarily the best. Any sequence which begins with an important point of contact for the individual or the group could be regarded as an improvement. Since little effort has been made to present the nature, the importance of invention and its effects educationally, the materials are poorly organized and adapted for this work. Consequently it will be necessary to make adjustments in the presentation, a few of which are suggested.

This outline may be used as the basis for a semester of integrated science-social science curriculum, or it may be modified for use as a single unit of three or four weeks' duration. In the first case there will be an expansion of the suggestions contained, with time to follow out corroborative and supplementary detail, giving therefore a deeper appreciation of what is happening. Alternatively, the main ideas only are developed as time permits and the supplementary material is omitted. Whatever alternative is selected will dictate the kind of instructional sheets prepared for use by the students.

The teaching procedures likewise must be adapted to the literature and time available. If there is an abundance of both, then each student may perform most of the activities and answer most of the questions. If not, a division of labor may be advisable, so that the essential points of the outline are presented to all, either by reading or through a system of reports and discussions. Some allowance for individual interests can be made by permitting a selection of specific inventions for study which are related in some fashion to the background and intentions of the student.

The objectives are used here as organizational headings for problems and questions. The bibliography and references have also been partially divided according to this scheme. In some cases a brief appraisal of the source is given, along with a suggestion as to pertinent sections or chapters. This, it is hoped, will make the unit more readily usable.

OBJECTIVES AND ANTICIPATED OUTCOMES

1. Understanding the nature and importance of inventions, discoveries and their relationships.
2. Understanding the evolutionary nature of the inventive process.
3. Knowing some of the basic inventions of prehistoric and historic times and their effects upon human life.
4. Learning how the rate of invention has changed and what factors have influenced it.
5. Understanding how and why invention surged forward during what is called the Industrial Revolution and thereafter—the effects of this revolution.
6. Appreciating the changed methods of invention occurring within the last century and its social implications.
7. Appreciating the character and results of the different kinds of opposition to inventions and their application.
8. Understanding the nature of automation; its principles and probable future effects.
9. Appreciating the impact of invention and technology on such things as war, international relations, cities, human relations, occupations, etc.

10. Knowing the social and anti-social uses of invention and technology.

11. Gaining the proper attitude toward inventors and the inventive process.

12. Appreciating invention and technology as a main force energizing and shaping our social evolution.

SUGGESTIONS ON CONTENT AND METHOD

Method and curriculum in education cannot be separated. Space, however, prohibits any detailed description of techniques, and in addition each teacher will have valuable individual ideas on procedure. In general, the reflective method has been found most effective, wherein each objective is approached by first raising questions which test old concepts, necessitate the reorganization of ideas and the search for new information. In such a manner, greater interest and motivation can be aroused.

From this point the skillful teacher is able to carry the group in the general direction of the unit while allowing for individual exploration along lines of particular interest. This of course is not absolutely effective, for interest is somewhat in proportion to knowledge, and on many of these objectives students may have little or no background. Also, it is vitally important to weave the conclusions in all the objectives into a unified outlook and not treat them as isolated facts.

A series of pertinent questions is proposed under each objective, and the first one is treated a little more fully in order to illustrate one way in which the subject might be approached.

Objective 1. What distinguishes western civilization and makes it dominant to others? What is the source of our industrial technology—on what is this based? Challenge the student to name any modern activity not revolutionized by invention. Throw out suggestions such as: What inventions made possible Columbus' discovery of America? Why wasn't it done in 892 AD? How have inventions made it possible for most of you to attend school? Name some of them. What inventions explain Mozart's musical style? What is the effect on inventions on: the kind of job you intend to get? The form of government we have? The fact that women are equal and allowed to vote? What you eat? Etc.

What is the difference between invention and discovery? Distinguish between primary inventions and improvements. What are the kinds of invention? Which usually receive the most attention? Why? What is the relation between pure and applied science? Is invention pure or applied? Why? Does the development of pure science have much effect on primary inventions? On additions to these? What is technology? What is its relation to science? To invention? What is the relationship between invention and industrialization. Are there such things as social inventions? Name some.

Objective 2. Ask who invented the radio (or telephone, steam engine, etc.). Take this invention and detail all the parts, improvements and contributions which went to make it into the present shape. At what point in this process is it complete? To whom should we give the credit? Have each student select some invention (see list under activities) and describe how it evolved in space-time. Why do you think inventions grew in this way? Why were so many inventions made simultaneously? Does any one country have a monopoly on invention? Why? Why do some countries hardly appear?

Objective 3. What were the main inventions of neolithic time which made possible group life? When is the neolithic? What does Childe mean by the "urban revolution"? By the "revolution in knowledge"? Explain how inventions lay behind these changes. Give an illustration of how inventions "fed upon each other" in a kind of chain reaction. Some have said that these were the most important inventions ever made. Do you agree? Explain.

Objective 4. Why was the rate of invention so slow in ancient times? Was the Middle Ages favorable for invention? Why? Name some outstanding inventions which were made during these times. When did the rate of invention begin to increase very noticeably? What inventions lay behind the growth of trade which sounded the end of medieval times? Describe the changes in the ship. What factors caused the rate of invention to increase? Did nations which encouraged invention (physical, biological, social) succeed better than those which did not? Give examples.

Objective 5. What is meant by the Industrial Revolution? Whose term was it? Was it a revolution? What caused it? What was the relation between it and the great growth of pure science during the 17th century? Name some of the important inventions which made it possible. How did the "chain reaction" process occur? Give examples. Why did the rate of invention mount so rapidly after this time? Describe some of the main and some temporary social effects of the Revolution.

Objective 6. What was the source of most inventions during the early 1800's? How were they

made? Who controlled them? Who reaped the profits? Answer these same questions for the period of the next century after that described. What is the significance of this change? In what way was it inevitable? What has been the relationship between the scientist and the inventor? Have inventors generally gotten rich from their inventions? What has been the chief motivation of scientists and inventors?

Objective 7. What groups have been opposed to the introduction of new inventions? Why? Give examples from business, labor, government and other groups. Is this opposition changing in any way? Why? Would you make any differentiation for the kind of inventions opposed? Why? Give examples of suppressed inventions. Is the patent system a vital influence today? Why? How long does it take an invention to get into general use? What is the significance of this?

Objective 8. What is automation? Who originated the term? On what general principles is it based? Give some examples of automatic factories and what they can do. How far developed is automation today? Suggest some future effects of automation on various businesses and occupations. Upon our future economic system. What sort of changes will be necessitated in education, occupations, economic and social organization? What is the relation of automation to invention?

Objective 9. Trace the effects of invention and technology on such things as: urbanization, occupational distribution, labor organization, sex equality, war, rise of the middle class, slums, crime, education and literacy, world organization, etc. Why do undeveloped countries want to industrialize? What are the advantages? What will be the effects where and when they do? What is the relationship between technology and specialization? Between these two and the degree of interdependence? Between cooperation and competition and technology?

Objective 10. List social and anti-social uses of invention such as dynamite, indigo dye, atomic energy, airplane, internal combustion engine, bacteriology, chemistry, etc. Where do inventors stand on this? Why does it happen? What is technological unemployment? Give some examples. Is it generally temporary or permanent? What can be done about it? Is automation likely to have some effects of this kind? What effect do inventions have on depression? Do inventors and scientists always understand what the effects of their work will be? Examples.

Objective 11. What danger exists when the public does not understand and appreciate the role of the inventor? Give some examples of this. What attitude should the general public have? What is the danger of interference with his work? What kind of inventions can be developed rapidly in authoritarian society? In a free society? Why? Give some examples. What do you think the long term effect of this is? What is the responsibility of the technologist to society and vice versa?

Objective 12. Explain how technology made slavery obsolete. How do you think technological discoveries are now making war obsolete? How did technology compel the phenomenon of mass production? What discoveries lay behind it? What effect did this have on classes? Marx once said that the means of production determine the relations of production. What does this mean, and to what extent is it true? Explain this statement by T. Swann Harding: "The discoveries of the scientist have done more to change the social order than all the reformers who ever lived." Give examples for and against this statement.

ACTIVITIES AND PROJECTS

The following constitutes a partial list of activities which may be performed and geared into the objectives and questions as suggested above. Many others may be added:

1. Make a list of simultaneous inventions and the countries where they occurred.
2. Visit the nearest research laboratories (college, commercial, government) to see how their work is carried on.
3. Have an inventor or researcher make a talk to the class on the nature of his work.
4. Analyze a business to see what changes have been introduced into it by inventions made during the last 25 years.
5. Make a graph showing the frequency of inventions or patents.
6. Make a series of sketches or models showing the evolution of an invention such as the steam engine, match, ship, printing press, etc.
7. Construct a windmill or water wheel and show it working. Explain its relation to slavery and to the rise of certain European countries.
8. Make a report on the life and work of some well-known inventor.
9. Describe in writing or orally the invention of John and Mack Rust, and how they have worked to see that it does not disrupt society and cause suffering.
10. Make a list of mechanical inventions around the home and estimate their effects on the home life and especially the condition of women.
11. Make a report on the history and development as well as the effects of inventions such as the following: aviation and the airplane, the ship, the automobile, writing, money, radio, linotype, sewing machine, atomic energy, lathe, hybrid seeds, rotation and fertilization of crops, vaccination, sanitation, sufferage, TVA, social security, transfusions.
12. Regard canned goods and packaged mixes as inventions. Discuss them as evolutionary growths, depending on prior discoveries (like

powdered eggs). Discuss their effects on the home and daily life.

13. Investigate music notation as a series of evolutionary inventions. Illustrate.

14. Visit an automatic factory or refinery.

15. Make a list of suppressed inventions, giving explanations.

16. Visit an auto assembly plant, packing house or other mass production operation. Report on inventions involved and social effects.

17. Visit a printing plant. Compare this equipment with the Gutenberg press. List some major effects of high speed printing.

18. Take one major invention and list additions or improvements made on it.

19. Make a criticism of the patent system and propose improvements in it.

20. Explain the psychological process underlying the making of inventions (See A. P. Usher in references).

EVALUATION

The success with which the objectives are achieved may be ascertained in several ways. The most common of these is the test. If a pretest was given, the results may be compared with those on the final test. Concepts are paramount to facts, however it is generally recognized that a test over concepts which gauges comprehension is not easy to construct and requires much ingenuity. Other methods are available for evaluation. If reports are made to the class, these may serve as an indication of what the student has gained. Written work may also be utilized, although this is often of questionable value. During the discussions of questions thrown out by the instructor or the exchange which takes place between the students, individuals may give much evidence of whether or not they have understood many of the objectives in the unit. Results on all these may also serve to evaluate the unit and the teaching of it, as well as the references in use to see wherein these have failed to achieve the established ends.

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CHARLES FINLEY HALL

THE newest addition to the New Jersey State Teachers College campus at Montclair, New Jersey, is the Charles Finley Hall. The new building houses the mathematics, chemistry, physics, home economics and fine and industrial arts departments. The building cost approximately a million dollars. Many older N.A.R.S.T. members will recall Dr. Finley as a charter member of N.A.R.S.T., an inspirational classroom teacher of Biology, and a distinguished college administrator.

A CONSIDERATION OF THE LEARNING PROCESS IN SCIENCE TEACHING

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MOST educators are familiar with the studies of educational psychology and detailed analysis of the complexities of the learning process. This paper will serve primarily as a summarization of the basic principles of learning with the implications for the secondary school science teacher. The investigation will not include data upon which the principles are based; rather, it will serve somewhat as a refresher of the basic psychological principles that a science teacher could advantageously use in developing satisfactory learning situations.

Learning is the primary function of the brain, and as such is a basic educative process. Adults are often inclined to take learning for granted because it is a process so familiar to matured people. In many instances, the difficult learning experiences of childhood are forgotten until they are recalled by observing the floundering tendencies of children in seeking correct solutions to immediate problems. For the teacher to understand learning processes in the science class room, it is necessary to first understand the general principles of learning. Many inferences can be drawn from a study of graphs of learning curves or reports on animal experiments; however, studying the nature of a specific process and the factors affecting it can result in a rather narrow concept. It is imperative that the teacher realizes that learning is not an *impersonal* process. A specific learning is only a part, an episode, in the learner's total complex life.

Man is an interacting and adjusting organism. Improvements through modification of man's thinking, feeling, and acting have been goals in the application of psychology to man's participation in society. Every science class can be considered an active little society which influences everything that everyone in that classroom does. Similarly, the ideas, attitudes, habits, and conventions of the home and community affect both the student and the school. It becomes vital, therefore, that each learning be considered in its larger setting: in relation to the learner, and in relation to the situation in which the learning takes place.

Whatever methods the science teacher uses to stimulate and facilitate learning, it must be remembered that it is *the student who does the learning.* Whatever the teacher should do is determined by the needs, interests, and ability of the individual learner. The sciences have long had a unique opportunity to capitalize on this idea through a variety of activities. Since young people are naturally curious and eager to learn of the world about them and their place in it, virtually every science classroom and laboratory experience can be set in a framework for a propitious learning situation if the teacher does his part in considering individual differences and presenting concrete, purposeful material for each learner.

GENERAL PRINCIPLES OF LEARNING

Modern psychologists are making rapid strides toward developing a systematic analysis of conditions under which learning may best take place. One can study many recent experiments on learning which have been reported in educational journals; however, the field is still young and the laws of learning are, to date, in a formative stage and should be considered more as working principles than as laws. In spite of the fact that the following psychological principles have been the basis for considerable controversy and criticism, they have played a prominent role in the development of educational methodology in this country.

Readiness and Material Relevance. It should be re-emphasized that a logical or-

ganization of subject matter in the school program should be complemented by a psychological organization—the emphasis being on the learner. If one were to trace an account of the phylogeny of learning, it would be apparent that the range of man's ability to learn is almost as great as that over the entire phylogenetic range below the human species. It is generally accepted that every person differs from all others in terms of needs, interests, and abilities as well as mentally, physically, emotionally, and socio-economically. Elementary school educators have long recognized that fact and have been developing teaching procedures and programs in relation to those differences in children. Secondary school educators have been slower in adopting policies recognizing those individual differences with the result that, while they may give lip service to the principles, many teaching practices actually violate rather than recognize the principles.

An interpersonal relationship between the teacher and individual students should exist in every learning situation. At any specific time, no two learners are equally ready to undertake a given task. The learner's ability, background, interest, physical and emotional conditions are all factors that will determine the efficiency of learning. Therefore, what is to be learned must be related to each student in these respects.

Thorndike, in 1913, first formulated the law of readiness: When a bond is ready to act, to act gives satisfaction; and not to act gives annoyance. When a bond which is not ready to act is forced to act, annoyance is caused.

The school learning situation and methods of teaching must be appropriate for each individual. Present-day schools are sometimes criticized for gearing the school program to the "normal" learner; or, as in the case of conventional secondary schools, standardized assignments force the students of low ability to attempt the impossible and often cause the students of high ability to "mark time" with materials not difficult enough to meet their demands. Under these conditions, the slow learners often tend to become discouraged and often rebellious, whereas the fast learners may develop slovenly study habits and can get into difficulties because the school program offers nothing to challenge their abilities.

It is vitally important that the science teacher secure favorable attitudes on the part of students, that tasks be assigned within the range and grasp of each student, that each student be allowed to progress to more difficult work within the limits of his particular abilities. If the science tasks are congruent with the student's experience to date, his home and community life, together with his felt needs and plans for the future, the material will appeal to him.

A brief summarization of this problem would state that the primary principle of learning is to relate goals and activities to the needs, interests, and abilities of each learner; or, more simply, using material meaningful for each learner; or, more simply, using material meaningful for each learner leads to more effective learning.

Practice. "Practice makes perfect" is a popular version of another fundamental principle of learning, namely, that all things being equal, practice strengthens, and lack of practice weakens the connection between stimulus and response.

Two corollaries of this principle may be recognized: (a) the "law of frequency" which states that learning is proportional to the frequency with which the learning factors are made operative; and (b) the "law of recency" which generalizes that other things being equal, memory will be better for recently learned habits than for those learned at a more remote time.

The reader must be cautioned, however, since there is considerable controversy over the validity of the law of practice and its corollaries. In actual use, practice does *not* always make perfect performance. Continued improvement takes place only if the practice is accompanied with adequate

motivation, other forms of reward, attention, and observation of results. It is generally agreed that sheer drill or repetition of a particular task does not necessarily result in greater learning, and may even lead to hate and repression.

Every teacher should understand certain factors in regard to the use of drill in the learning process. In the case of learning motor skills, drill plays an important part in developing efficient responses. This can be illustrated by such tasks as learning to drive a car, typewriting, or playing a musical instrument. However, in any tasks of similar nature inefficient habits can also be formed through practice. Intelligent practice, of the proper kind and amount, is essential for developing perfection in performance. The same principle can be applied to verbal skills but does not necessarily include the development of concepts. Science principles can be learned by rote methods but this lack of conceptual growth assures the student of only a small degree of learning of any lasting nature.

There is a definite place for drill, but the teacher should adopt a Golden Mean—use the practice in moderation. If certain basic principles relating to drill are applied in teaching techniques, the learning situation can be relatively effective:

1. *Drill must be meaningful and purposeful to the learner.* Efficiency of learning will be greater for students who have a genuine desire to learn scientific principles than for those who merely take a course to build up credits for college entrance or are forced by the high school curriculum requirements to attend class. Intrinsic motivation is rarely built up in the latter group; however, it presents a challenge to the alert, conscientious science teacher to supply adequate extrinsic motivation to stimulate a desire to participate and learn.

2. *Related concepts developed through previous experience lessens the amount of drill necessary for adequate efficiency of response.* A student who has been exposed to considerable laboratory experiences in chemistry and who has developed meaningful mathematical concepts will require a lesser degree of drill in remembering a chemical or mathematical formula than a person who is required to learn the principles or symbols without understanding the concepts involved and the calculations needed.

3. *There is a value in distributed learning.* A rather simple method of improving learning and retention is to distribute the learning over a number of short periods with rest intervals instead of massing the learning in one period. The teacher must give consideration to what occurs immediately after the study period. Tasks of a similar nature may interfere with the previous learning. Thus, if the science student has been learning via dissecting the circulatory system of the frog and follows it by a similar procedure on the crayfish, the memory for the former will be considerably less than if following the original learning by an unrelated activity like playing baseball. No set rule can be stated, however, since there are so many variables: student maturation or physiological conditions, motivation, nature of the task, and so on. In most cases, the principle of distributed learning is of value to the teacher.

4. *Drilling on parts of a total organization should be done in terms of the larger whole or meaning.* If a material is a meaningful "whole" to a learner, he will learn more readily than if the material seems to be a collection of fragments. If the student is studying a particular chemical process, he should read through or be familiar with the entire process before commencing any specific part. There has been much controversy on "part" vs. "whole" learning or a combination of both in some cases. The fact to be remembered is that the efficiency of the mode of attack is improved as the meaningfulness of the material is brought to the attention of the learner. Obviously, if the student is learning a table of chemical elements in which parts of the series will be used separately, there is a disadvantage in learning the table as a whole. The student might have to repeat large portions of it

whenever he wanted to use any part of it. In this case, learning by large meaning implies the learning of each combination in many applications.

Effect. In essence, this principle states that rewards strengthen and failures weaken the connections between situations and response. Extinction of unrewarding responses usually occurs.

In human experiments concerning the amount of reward, the results seem to favor: (1) when there is considerable reward, learning occurs; and (2) when there is no reward, learning generally does not occur, and in case of established habits, extinction takes place.

It is not feasible to examine closely the various aspects of the law of effect in spite of their importance in the teaching situation. The reader is referred to McGeoch and Irion's competent treatment.[1]

FACTORS CONDITIONING LEARNING

The first problem in learning may be stated as the provision of desired goals and activities which are best suited to the needs, interest, and abilities of the individual learner. The efficient control of the learning process is a complex task. The most difficult and important job that the teacher faces is student motivation. Strong motivation can overcome certain readiness difficulties; or, on the other hand, if a student is more motivated to do something else, the teacher may find little success with his "adjusting" methods.

Motivation. The term motivation has been given a number of definitions by various investigators. For the purposes of this paper the definition of McGeoch and Irion will be used, namely:

> a motive or motivation condition is any condition of the individual which initiates and sustains his behavior, orients him toward the practice of a given task, and which defines the adequacy of his activities and the completion of the task.[2]

[1] J. A. McGeoch, and A. L. Irion, *The Psychology of Human Learning.* New York: Longmans, Green and Co., 1952.

[2] *Ibid.*, p. 194.

From this definition, one would expect to find motivated students to be more active than unmotivated ones; and this is often used as a criteria for judging the strength of motivation in the classroom.

The science teacher's task is not one of merely attempting to awaken a desire to learn in a passive student, but rather to so effectively relate the material to each student's felt needs that he wants to carry on school tasks and learn. Many factors are involved. The following are the most common incentives that the teacher should consider:

1. *Interests and sex-social drives.* Apparent interests should be considered, but it is also necessary to see behind them the basic drives and needs. To be effective, motivation should reach back, recognize, and utilize these basic urges. Among secondary school students these basic urges would include the desire to have the approval of both the young people and adults with whom students associate together with some measure of status and prestige. If these basic sex-social drives can be met in connection with schoolwork, the student will find satisfaction and apply himself to the tasks at hand; otherwise, he may seek satisfaction in some other way. This is a contributing factor to the great number of drop-outs in the sophomore year.

2. *Drive to activity and curiosity.* The school should give ample opportunity for the satisfaction of natural activity and curiosity drives. The science classes have long possessed ideal opportunities for exploration of many concepts and principles. If these scientific ideas and concepts are presented to the students in a meaningful and purposeful way, rather than sheer rote learning, the science teacher will find the students to be eager, alert, and intelligent learners.

3. *Intrinsic and extrinsic motivation.* Motivation may be either intrinsic or extrinsic. If a science student finds the material so meaningful that he desires to work through sheer interest within the activities

themselves, learning has its own reward and motivation, then, it is intrinsic—it comes from within. However, this ideal situation is not always easily maintained. Extrinsic motivations like fear of reproof or punishment are rather ineffective. However, if a response is punished and the learner is allowed to terminate the punishment by doing something else, the latter response will be learned. This is due to the fact that escape from the punishment or reproof serves as a reinforcing state of affairs.

In using praise or reproof, the teacher should bear in mind that both may have similar effects in spurring students to greater effort; or, the adverse may be true, also. It is necessary for the teacher to understand each learner and observe the effects of praise or reproof on each individual. It is generally agreed, however, that praise has more advantage in the normal classroom situation than has reproof. In a final analysis, the effects of praise or reproof, depend upon the personality of the teacher and the learner, presence and reaction of the other students, and the particular learning situation and task.

4. *Informing students of progress.* Knowledge of his personal progress has a tendency to serve as an incentive to the learner. In grading tests, or other evaluative instruments, it would be wise for the teacher to reveal, in addition to a single score or mark, an analysis of the student's strong and weak points. By doing this, the grading will be more significant if the student realizes that although he is weak in certain specific subject matter, he is also strong in others; thus, the grading will have a positive, as well as negative, effect.

The teacher should correct evaluative materials and return them promptly for two reasons. First, a prompt return assures the student that the material was important enough to warrant the instructor's attention. Secondly, a prompt return gives the student an opportunity to correct specific points of error or omission while the topics are still fresh in mind and before new learnings or interferring materials lessen the memory value of the original learning.

The teacher should recognize and interpret the performance of each individual in terms of personal as well as group progress. Total scores may still place an individual in the same class rank, yet he may make improvements that are conspicuous in terms of his own ability. These points should be recognized so that each learner may have some basis for prestige. Any gain over past performance should be recognized. Several failures can be overcome by recognition of one learning success.

Emotional Factors. Emotional factors are not concomitant of a learning situation, but have strong hindering or facilitating effects. If a student feels that a specific learning satisfies a felt need, he will be pleasantly affected; if, on the other hand, he feels frustrated in meeting his desires, an unpleasant emotion results. Significant learning cannot be a mere collection of facts and understandings, a cold, impersonal assimilation; rather, it is a pleasantly exciting discovery of new satisfactions of needs and interests. There is a definite place in every learning situation for mild emotion; this serves as a tonic effect. Strong emotions elicited from a drive in process of fulfillment may serve as a marked stimulation on the schoolwork involved. Only severe frustrations and distresses of emotional shock will interfere with school tasks. The science teacher should beware of presenting material that is drab and emotionally colorless; the material should foster pleasant emotional experiences. Again, the teacher must know and understand the individual learner, his abilities and emotional life, if the tasks in the classroom are to progress effectively.

Environmental Factors. Sociological factors within the classroom will determine the effectiveness of learning; eager cooperation or grudging appeasement can result. The presence of cliques or social isolates may precede the importance of class work in many instances. Efficiency in learning may be stimulated or hindered by

the partner or associates a student has in a science classroom or laboratory. The social atmosphere should be cooperative and free from conflicts; it should develop a spirit of friendly association toward the achievement of common goals.

Understandable and reasonable requests and directions must be given by the teacher. To assure good acceptance, they must be stated in a manner to be specific in direction, yet not arouse resistance.

Outside-school influences should be considered. It should be further emphasized that students do not discard the effects of home and community life as they enter the classroom; these influences are responsible for a great portion of a student's personality traits, together with the fact that many personal home or community problems may affect the learning of the school work at hand. Understanding is required by teachers in many cases; if learning seems greatly impaired due to outside factors, perhaps an analysis of the problem should be made by a competent individual.

The classroom teacher is often accused of almost completely ignoring the physical aspects of the learning situation. Hearing occurs best when physical conditions are optimum. Mental and physical fatigue are accentuated when the best conditions are not maintained. The science teacher should be the first to insure that heating, lighting, ventilation, and pleasant atmosphere are the best. In addition, seating, laboratory equipment, room acoustics and similar factors play an important role. The science teacher can assume leadership in advancing improvements of this type. The science classroom can easily capitalize on the high-dividend use of a variety of displays to enhance the physical environment.

A classroom or laboratory library of books on topics related to those being studied would encourage free-reading and thus stimulate progress in learning. Any modern, alert teacher recognizes the importance of learning situations to be found best outside of the school; the science teacher will fully utilize community resources and personnel both in the classroom and through field trips, and so on.

It should be remembered, however, that to simply have a congenial class under affable control, which has good equipment and books, and takes interesting field trips is not sufficient. The good teacher will constantly be aware of not only the mental health of the students but, also, their learning efficiency.

The learning objectives developed by science education authorities include:

1. Functional understanding of science principles and concepts.
2. Formulation of desirable science attitudes.
3. Opportunity for learning in the area of scientific method of problem-solving skills.
4. Competent utilization of manipulative devices and instrumental skills with science equipment.
5. Development of appreciations and interests in science.

APPROACHES TO THE LEARNING PROCESS

Learning as a Process of Experience. Modern educational theory realizes that many of the aims of education cannot be met merely by reading books or listening to lectures. Instead, learning must be a process of rich and wide experiences in actually *doing the things.* It is a process which developes, in addition to actual abilities, certain desired appreciations, attitudes, and understandings.

In schools where this principle of experiencing is considered a definite part of the learning process, field trips, construction, laboratory and library research, and group planning and executing are necessary parts of all classroom situations. Audio-visual materials are making learning situations more realistic and educative than through mere lecture, study, and recitation.

It must be emphasized, however, in removing any possible misunderstanding stemming from the above statement, that more reading is required, not less, to make an experience curriculum in the classroom.

Science research projects cannot be carried on through the use of a single textbook; many sources are needed to complete real and meaningful experiences.

Learning as a Creative Process. In today's schools, creative ability is being recognized in degree, not kind. Formerly, emphasis was placed primarily on learning to be intelligent consumers in areas of expression rather than producers. It is recognized today that every individual possesses creative ability to a greater or lesser degree in every area of human expression. The changing concept of a creative act is the reason for this difference in analysis. In past years, to be considered creative, an act had to withstand the tests of time and originality; it had to be recognized for decades and centuries as the work of a master. But now, a test for creativeness is in terms of its producer; it is creative if it is original or an improvement of a past performance no matter how it compares with the production or performance of others.

Thus, student self-expression is being emphasized in all areas of learning. Science teachers can encourage students to make a variety of manipulative devices, contrivances, three-dimensional objects, and so on, in contrast with former emphasis on the student being a passive observer or listener.

Learning as Reactions to Whole Situations. In an earlier section of this treatise emphasis was placed on learning by wholes. The important point for a teacher to realize is that at all times he should be concerned with the total learning situation. Driving students of low ability into impossible learning situations often causes serious failure complexes in that and related learning areas. A dictatorial teacher stifles desires and abilities to do self-planning, both individually and in group work.

In specific subject matter learning, it is generally agreed that the value of meaningful organization lies in the material's meaningfullness for the student, not for the author of the material or the teacher. For example, in studying a particular phyla, such as Platyhelminthes, it has little meaning in the evolutionary sequence without a previous introduction to the biogenetic theory. In other words, an over-view of the entire animal kingdom, ranging from phylum Protozoa through Chordata, will enable the learner within a single or limited number of class sessions to grasp the position of each broad family grouping in the total evolutionary picture.

TRANSFER IN LEARNING

There has been considerable controversy on the problem of how transfer takes place and the conditions under which learning in one situation will transfer to another situation. It is becoming apparent that generalizations form the basis for much transfer and that the greater the experience from which these generalizations are derived, the greater the probability that they will be applied to related situations. Students who developed rather advanced concepts of science principles through a wide variety of experiences may be more inclined to apply these learnings to later situations than will one who has merely memorized statements and definitions of principles. Broad experiences in actual application of science concepts to life situations may increase their later use in situations that might be unnoticed by a student who had mastered only rules of processes and applied them to theoretical situations.

Recent research studies have been conducted by the investigator with the problem of whether or not scientific principles, attitudes, and skills of the scientific method of problem solving represent feasible objectives in science teaching. The evidence from these studies indicates that the learning of scientific principles, attitudes, and skills are not concomitants of learning and that there is a definite need for special, direct attention to be given to them in the

classroom. The author found that students of high and low ability were significantly better in making applications of biological principles when the instruction placed emphasis on such application. It was also found in a study of the achievements of a group of students with respect to development of scientific attitudes and skills in the scientific method of problem solving as measured by their ability to make accurate observations, draw inferences, and weigh evidence that the students were inclined to be impressed by advertisements and to accept misleading generalizations unless specific instruction and laboratory experiences accompanied the reading of the advertisements.

Basic principles of learning have been reviewed in this article. One additional fact must be stated; teaching is the stimulus, learning is the response. The science teacher's function is to provide the most effective stimuli in order that the best learning can take place. Knowing the basic principles of learning does not guarantee that good teaching will be done—the teacher must apply this knowledge correctly. The final test of good teaching is whether the student learns as much as his ability warrants under the desirable milieu described in this discussion!

PRINCIPLES OF GENERAL BIOLOGY FOR PROSPECTIVE ELEMENTARY SCHOOL TEACHERS *

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To prepare elementary school teachers to teach about plants and animals, certain acquisitions of understandings of principles of general biology should be assured. To effect this, there is a need for ascertaining which principles an elementary school teacher should understand in order to be prepared to teach about living things.

An analysis of principles of biology from the point of view of a select group of elementary school teachers throughout the country should provide college instructors with a list of principles which may be included in a course designed for pre-service teachers.

PREPARING A LIST OF PRINCIPLES OF BIOLOGY WHICH ELEMENTARY SCHOOL TEACHERS SHOULD UNDERSTAND IN ORDER TO TEACH ABOUT PLANTS AND ANIMALS

In order to determine which principles are considered important, the opinions of elementary school teachers were canvassed. The method by which this was accomplished was to select a group of in-service teachers in elementary schools and have this jury rate a validated list of 106 principles of general biology.

A Validated List of 106 Principles of General Biology

A tentative list of principles was compiled utilizing educational periodicals, twenty-three textbooks in college biology used at fifty state teachers colleges, six series of science textbooks for grades one through six, and fifty courses of study in general biology from state teachers colleges.

Checking the list of principles for technical accuracy and completeness of coverage.—In order to be reasonably certain that the list of principles was technically accurate and covered the field of general biology, the list was submitted to five college professors who taught courses in biological science that are required of prospective elementary school teachers. Subse-

* This article is a report of one aspect of a doctoral dissertation study entitled "Considerations in Selecting, Developing, and Validating Laboratory Experience Units in General Biology for Prospective Elementary School Teachers," conducted during 1956 at North Texas State College, Denton, Texas.

quent to the validation, the list was modified according to the recommendations of the jury.

Classification of principles of biology into content areas.—The 106 principles were categorized into specific content areas, as suggested by the principles themselves. The titles of each area, and the number of principles assigned to each of the ten areas are summarized in Table I.

TABLE I

The Ten Content Areas of General Biology Suggested by the Nature of the List of 106 Principles, and the Number of Principles of Biology Classified into Each Area

Content Area of General Biology	Number of Principles
I. Nature of Life	7
II. Earth's Food Supply	14
III. Knowing Plants and Animals	18
IV. Survival of Living Things	23
V. Caring for Plants and Animals	7
VI. Using Plants and Animals	10
VII. Behavior of Living Things	5
VIII. Health and Disease	7
IX. Reproduction and Development	6
X. Heredity and Variation	9

Bases for Selecting a Jury of Elementary School Teachers

The jury consisted of fifty-six in-service elementary school teachers. The following bases were utilized in selecting elementary school teachers to membership in a jury for the purpose of rating the list of principles of general biology:

1. Evidence of strong interest in elementary science education by having published articles dealing with elemenetary science, or
2. Recommendation to membership in a jury by a leader in the field of elementary science education.

The Rating Form for the Evaluation of Principles of Biology

The rating form consisted of 106 statements of principles of general biology, using a three-point rating scale. To the left of each statement of a principle were the code letters "VI," "I," and "O." The following interpretation was ascribed to the code letters: *VI, Very Important; I, Important;* and *O, Just as Soon Omit This One.*

Treatment of the Data

Code values.—The three code letters were assigned the following numerical values: VI = 4, I = 2, O = 0. Each principle was assigned an index of importance, or average judgment value based on the sum total of the individual judgments of fifty-six teachers.

$$\textit{Index of Importance} = \frac{\text{Sum total judgment values}}{\text{Number of jury members}}$$

Estimating the reliability of the scale values.—To determine the consistency with which members of the jury rated the principles of biology, the Pearson's product-moment coefficient of reliability was computed by the split-half technique, and corrected for length by the Spearman-Brown formula. The group of fifty-six teachers was divided into two groups, so that each group consisted of twenty-eight jurors and represented the returns of teachers from grades one through six. The correlation coefficients for each of the ten content areas are summarized in Table II.

A List of 106 Principles of General Biology in the Descending Order of Their Importance for Elementary School Teachers to Understand in Order to Teach About Plants and Animals

The average judgment value was computed for each principle, and this index of importance was used to establish the rank of a principle among the 106 principles. The following is a list of statements of principles, their rank and rating:

Rank	Rating	Principle
1	3.68	Plants serve man by providing him with the different classes of food which are necessary for his everyday activities.
2	3.64	Roots of plants are adapted structurally to absorb water from the soil and transport it to the leaves where it may be used to form food; most of

TABLE II

SCALE RELIABILITY COEFFICIENTS FOR THE RATING OF THE PRINCIPLES OF GENERAL BIOLOGY IN EACH OF THE TEN CONTENT AREAS AS RATED BY TWO SELECT GROUPS OF TWENTY-EIGHT ELEMENTARY SCHOOL TEACHERS IN EACH GROUP

Content Area	Pearson's Coefficient of Correlation	Reliability Coefficients *
I. Nature of Life	0.90	0.95
II. Earth's Food Supply	.98	.99
III. Knowing Plants and Animals	.90	.95
IV. Survival of Living Things	.92	.96
V. Caring for Plants and Animals	.95	.97
VI. Using Plants and Animals	.95	.97
VII. Behavior of Living Things	.86	.92
VIII. Health and Disease	.93	.96
IX. Reproduction and Development	.98	.98
X. Heredity and Variation	0.95	0.97

* Estimated scale reliability using fifty-six sets of scale values, as corrected for length by the Spearman-Brown formula.

Rank	Rating	Principle
		the water evaporates if the leaves are thin.
2	3.64	After a seed has germinated, it needs sunlight to continue its growth into a mature plant.
2	3.64	Disease germs may be spread from one place to another through different media; dust, liquids such as sputum and droplets which are given off during coughing and sneezing. In some instances, food is a carrier of disease germs.
5	3.57	In man, food and oxygen are carried to all parts of the body through a system of blood circulation.
5	3.57	Certain harmful bacteria enter our bodies at specific points; the most common portals of entry are the mouth and nasal passages since these places usually provide the bacteria with food, moisture, and proper temperature for their development.
7	3.50	The ultimate source of all energy is sunlight, and this energy is bound into food materials during photosynthesis.
8	3.47	Plants aid in conserving and renewing the mineral content of soil; replanting trees and shrubs, and grasses helps to keep the soil intact and free from the ravages of wind and rain, and the plant roots act as "elevators" to bring minerals to the surface.
9	3.43	Animals help plants in different ways; some animals may eat animals which are destructive to plants; animals help to pollinate flowers, thus assuring some degree of fertilization; animals help to scatter seeds of plants which helps to insure some plant propagation; many animals are known to devour their own young, a form of be-behavior which is instinctive and helps to regulate the population growth.
9	3.43	Birds adapt to changing atmospheric conditions of their environment; certain birds migrate at different times during the fall, and to different parts of the world depending upon the species.
11	3.39	Some animals such as birds can be recognized by their color, form, song, activities, and by the nature of their homes.
12	3.35	The cell is the structural and functional unit in most living things.
12	3.35	Seeds contain a plant embryo which can begin its growth only if it can absorb water and oxygen from its environment.
12	3.35	Seeds and fruits contain food materials which have been stored as surplus food. This material may be used by the seedling during its growth, or may provide much of the food

Rank	Rating	Principle
		used by man, birds, and other animals.
15	3.31	Trees show specific formations in the structures of leaves, bark, cones or flowers, buds, and the way of branching which enables us to distinguish them.
15	3.31	The bodies of man and other animals require a constant supply of oxygen; some animals obtain their oxygen from liquids; whereas others can take oxygen directly from the atmosphere.
17	3.28	Green tissues of plants are the principal food factories since they contain the chlorophyll in the chloroplast which is necessary for food making.
18	3.23	Under certain circumstances, color in animals may conceal them in their habitats, or call the attention of other animals toward themselves.
18	3.23	Bacteria will contaminate and spoil food whenever nearly optimum conditions of temperature and moisture exist in the food material.
20	3.18	Oxygen is delivered to animal and plant cells where it may assist in the oxidation of food materials, resulting in the release of energy.
20	3.18	Animals possess certain structural and physiological characteristics which enable them to live in the different geographic zones in which we find them.
20	3.18	A "Balance of Nature" is accomplished through the interrelations of plants and animals with each other, and with their physical environment.
20	3.18	Many animals which remain in their environment during the changing seasons are forced to change their ways of seeking food; in some instances, animals become dependent upon man for their survival.
24	3.14	The oxygen of the atmosphere is removed by living things and returned to the atmosphere by chlorophyll-bearing plants during photosynthesis.
24	3.14	Certain structures of mammals make it possible for animals to move on land or in the water, and to secure their food in different ways.
24	3.14	Some plants change structurally in response to the changing seasons; some plants lose their leaves and enter a dormant period of survival; some plants retain all of their structure but enter a period of much reduced metabolism; some plants lose the entire plant structure above the ground, and develop a new set of structures in the spring.
24	3.14	Insects respond to the changing environment by laying eggs in cases, by digging into the earth, or by migrating from summer homes to winter homes. Most of the insects do not adapt to seasonal changes and die.
24	3.14	Some animals are born helpless, and are completely dependent upon their parents; other animals are independent of their parents from the first day of their birth.
29	3.11	Man, if he is to survive, must learn to use wildlife resources without at the same time leading to their disappearance.
30	3.07	The moisture requirements of plants vary among certain species, some plants thrive only in damp places, whereas other require small quantities of moisture, thereby enabling these plants to live in relatively dry places and in areas where rainfall is sparse.
30	3.07	Animals eat different varieties of food materials, and thrive best when provided sufficiently with their specific dietary needs, particularly proteins, fats, vitamins, and complete mineral requirements.
32	3.04	Many insects in their feeding habits interfere with the health and growth of man's cultivated varieties of plants, and with the health and growth of domesticated animals.
33	2.96	Plants vary in the amount of sunlight which is required for continued optimum growth; some plants thrive best in the sunlight, whereas other plants require a definite amount of shade and will die in direct sunlight.

Rank	Rating	Principle
34	2.93	Birds secure their food from sources such as mud, water, land, and air through the use of their beaks; the type of beak limits to some extent the source which can be exploited.
34	2.93	The light requirement of plants varies with the species; some plants will thrive only in sunlight, whereas others thrive in shade or partial shade, and would die in direct sunlight.
34	2.93	Communicable diseases are caused by specific microorganisms.
37	2.86	There is a variation in the time of bloom among many plants. The flowers and seed which are produced are characteristic of the plant.
37	2.86	Many groups of animals live together and form different kinds of homes in the water, on land, and in vegetation; some homes serve as resting places for the adult animals, others house the young.
37	2.86	All cells arise through the division of previous cells, and living things arise from living things like themselves.
40	2.82	Man has tried to restore many animal habitats which have been endangered by man's change of the environment, in order to create favorable living conditions for the continued existence of species in certain land areas.
41	2.79	Animals in captivity thrive best and reproduce their species when the environment intended to surround them simulates their original home surroundings.
42	2.75	Higher forms of animals possess different kinds of sense organs which make it possible for these animals to become aware of their environment; in man, the sense organs of sight and hearing are very important.
43	2.71	Food is produced by the green tissues of plants as simple carbohydrates, and synthesized into sugars, starches, fats and proteins.
43	2.71	Buds are quite rich in food materials, and are frequently eaten by birds, squirrels, and people.
43	2.71	The bodies of some animals are adapted to care for their young during the process of development of the embryo, whereas other animals provide some means within which the young develop outside of the body of the parent.
46	2.68	Changes in the earth's surface conditions, and the inability of animals to respond effectively to past conditions may have helped to bring about the end of many animals.
46	2.68	Parts of plants and animals, or their by-products, have helped to provide material resources for the manufacture of medications which have helped to prevent and/or cure diseases of the body.
48	2.65	Many kinds of plants and animals have entered and accepted our habitat due to the availability of food and man's care.
48	2.65	Mouth parts of some animals make it possible for them to eat plant materials, whereas other animals are meat eaters, or eat both plants and animals.
48	2.65	The bodies of some animals go through a series of body changes before they look and become like the adult of that species. A few animals become adult and remain in the larval stage.
51	2.61	Minerals for plant use must be soluble in water so that they may be taken into the body of the plants through the root hairs.
51	2.61	Some plants require special soil conditions for growth; some plants require an acid soil, whereas other will grow well only in alkaline soil.
51	2.61	Man and his numerous activities have been responsible for the disappearance of more recent animals than any 'other other factor in the environment.
51	2.61	Some birds contribute to man's welfare by keeping down insect populations which are vectors of disease and destroyers of vegetation and food. Mostly birds aid in restoring fertility to "worn out" soils and waters depleted of soluble minerals.

Rank	Rating	Principle
55	2.57	Specific antibodies have been produced in other animals for purposes of developing immunity in man, and for curing some diseases in man.
55	2.57	All living things are subject to change both structurally and functionally. Some living things have not changed noticeably for millions of years.
57	2.54	Cultivation tends to rid the soil of undesirable plants; some plants consume much moisture and many valuable minerals from the soil, and in this way affect the growth of those plants which seem more important to man.
57	2.54	Certain marine resources have been especially useful to man in providing for sports activities, food materials, and by providing material resources for the development of industries and subsequent employment.
57	2.54	Some larger animals exist in sufficient numbers to provide for sports activities such as hunting and fishing; some have been killed in such large numbers as to bring about the extinction of many wildfowl and some mammals.
57	2.54	Certain groups of bacteria and molds serve man in the manufacture of food varieties and by decaying food materials.
57	2.54	A study of fossils indicated the past existence of some plants and animals which are now extinct, as well as some plants and animals which are living in different parts of the earth today and resemble the ancestral stock.
62	2.47	Some animals are incapable of continuing in their present environment, and need our help to survive.
62	2.47	Many plants die when moved into our homes in winter because of excessively high temperatures, low humidity, and reduced light intensities. Some plants will die because the soil is warm and full of water and carbon dioxide that suffocate the roots.
62	2.47	Every individual grows from a single cell; in some groups of plants and animals, unfertilized eggs develop into embryos, other individuals may develop from spores.
62	2.47	Some animals appear to have body structures which are resistant to the attacks of its enemies.
66	2.43	Although aquatic animals are alike in many ways, they do show structural differences in food-getting, respiration, and locomotion.
66	2.43	The fermentation ability of some plants has made it possible for us to use them in cooking, baking, and in the beverage industries.
68	2.39	Blood in man is composed of different liquid and solid constituents; some parts conduct the food and exygen to body tissues, whereas other components may combat disease germs to a limited extent, or stimulate body metabolism by carrying hormones from one part of the body to another.
69	2.32	The human body may be stimulated to produce disease-resisting antibodies by injections of poisons produced by certain harmful bacteria, or by injections of weakened, or attenuated bacteria for which a specific immunity is desired.
70	2.28	Producing large numbers of offspring is some assurance that a few of the offspring will likely find a suitable place in which to grow and develop.
71	2.25	In higher forms, cells are grouped to form tissues with both general and specific functions.
72	2.20	In higher forms, tissues are organized into organs, and organs into organ systems, each carrying on the various functions of living things.
73	2.18	Man has employed the knowledge of the inheritance of characteristics in living things to produce a few living things with characteristics to suit his needs.
74	2.14	Food materials may be absorbed as food soluble in water, or ingested by some animals as food particles.
75	2.06	Most plants lacking chlorophyll cannot produce their own food materials, and must

Rank	Rating	Principle
		depend upon other plants for food, including man, and obtain this food by absorption of food from its host, or from existing organic food.
76	2.04	Animals are classified into groups on the basis of specific structural characteristics which are possessed by the animals; animals having the same set of specified characteristics are then classified into a group.
77	2.00	Although lacking in a nervous system, some simpler forms of plants and animals react in specific ways to stimuli such as sunlight, water, gravity, and temperature.
78	1.93	With few exceptions, the range of temperature for the life activities of living things varies from many degrees below zero to nearly the boiling point of water.
79	1.89	Food materials stored in underground structures such as rhizomes, tubers, bulbs, and corms may provide the "undifferentiated" structures with nourishment.
80	1.86	The cell consists of a mass of protoplasm which is usually differentiated into an inner portion called the nucleus, and an outer portion the cytoplasm; a plant cell possesses a cellulose wall, whereas the cell wall in animal cells consists of a membrane.
80	1.86	Microorganisms are likely to appear in a habitat in large numbers when conditions of moisture, temperature, and food availability is nearly optimum.
80	1.86	The protoplasm of plant and animal cells passes on from one generation to another as a result of cell division.
83	1.78	Enzymes, or digestive juices are produced in different parts of the food tract, and act upon specific classes of foods.
84	1.75	A carbon cycle in nature occurs as a result of the decomposition of carbon compounds of organisms which replenishes the carbon supply in the atmosphere. The carbon dioxide is needed as raw material to produce carbohydrates.
84	1.75	Green plants which last from one season to another, may or may not store food materials in the roots during the summer.
84	1.75	The male and female sex cells contribute equally to the complement of heredity characteristics in a fertilized cell.
84	1.75	The human body produces chemical substances called enzymes which are capable of breaking down insoluble substances into soluble materials.
88	1.72	Cultivated flowering shrubs and evergreens which are used around the home for landscaping purposes, have been changed or "moved" to such an extent that they would not ordinarily exist without man's care.
88	1.72	New types of living organisms may arise through mutation.
90	1.68	All animals react to stimuli; the nature and extent of the reaction to certain stimuli will depend upon the complexity of the animal's nervous system as well as other bodily structures.
91	1.64	Firm outer structures and special root systems of some plants are found to be resistant to the damaging effects of changing atmospheric conditions.
92	1.60	Animals not closely related may appear as similar life forms.
92	1.60	Hereditary characteristics may not show in plants and animals for several generations, yet may be expressed in an offspring as a result of a given combination of genes.
94	1.57	Some bacteria affect human tissues by the toxins which they produce, whereas others affect tissues by feeding on body tissues and fluids thereby disrupting normal tissue function.
95	1.53	Plants not closely related may exhibit similar life forms.
96	1.46	With an increase in body size and general complexity of organization of the body of an animal, there ensues a corresponding elaboration of the transportation mechanisms for food and oxygen.

Rank	Rating	Principle
97	1.43	Skins of many reptiles are of special economic importance to us in providing clothing and luxuries which enable us to resist the changing environment.
98	1.39	Cell division is a fundamental process of reproducing cells in organisms whose cells contain nuclei. Nuclear division sometimes occurs without cell-division.
99	1.21	Sperms and eggs from hybrid individuals combine at random in all ways possible according to chance during the fertilization of an egg, hence giving rise to many combinations of hereditary characteristics.
100	1.14	Nitrogen-needs of plants in nature are supplied by some nitric acid produced in the atmosphere as well as by nitrogen-fixing bacteria which are capable of taking free nitrogen from the air and combining it with oxygen to form nitrates, and by the mineral components of soil resulting from the breakdown of organic matter.
100	1.14	Some forms of behavior in man are the result of the involvement of his cerebral cortex, whereas other behavior does not require the facilities of cerebral centers of the brain.
102	1.10	Adaptations which have allowed organisms to remain and reproduce, will remain as features of those organisms, even if the adaptation appears to be "worthless."
103	1.07	Saprophytes cause decay by which process necessary raw materials are produced from dead matter which may be used in the production of new organisms.
104	1.03	Hormones are chemical substances produced in certain parts of the human body, and stimulate the body into specific activities depending upon the type of hormone which is secreted.
105	0.91	Chromosomes are portions of the chromatin material within the nuclei of cells, and are most readily observed during the process of cell division.
106	0.82	The diffusion of molecules of a fluid through a semi-permeable membrane from a region of higher concentration to a region of lower concentration is an important process in living things.

SUMMARY

1. There was a strong agreement among the select jury of fifty-six elementary school teachers concerning the importance of certain principles of general biology which an elementary school teacher should understand in order to teach about plants and animals. The reliability of the scale values for each group of principles within each of the ten content areas of biology was 0.92, or better.

2. Thirty-two principles were rated 3.0, or better, which is halfway between a rating of *very important* and *important*. These principles were most common to the following content areas of general biology: *Earth's Food Supply,* 50 per cent of the principles in this area were rated 3.0; *Health and Disease,* 42 per cent; and *Survival of Living Things,* 39 per cent.

3. Twenty-nine principles of general biology were rated less than 2.0, indicating these principles to be least important for an elementary school teacher to understand in order to teach about living things. These principles were most common to the following content areas of biology: *Heredity and Variation,* 66 per cent of the principles in this area were rated less than 2.0; *Behavior of Living Things,* 60 per cent; and *Reproduction and Development,* 33 per cent.

4. The following content areas of general biology, as categorized in this study, did not contain a single principle with a rating of 3.0, or better: *Behavior of Living Things, Reproduction and Development,* and *Heredity and Variation.*

BOOK REVIEWS

RUNES, DAGOBERT D. *Treasury of Philosophy.* New York (15 East 40th Street): Philosophical Library, 1955. 1280 P. $15.00.

In this comprehensive collection of philosophical writings are to be found not only the great thinkers of the West, but many of the important and less well known philosophers of the Orient. The selections cover the whole span of recorded philosophy from the 6th century B.C. to the present.

Alphabetical in treatment, each of the hundreds of entries is complete with a short biographical sketch and a selection from the more important writings. Brief and to the point, each sketch outlines its subject's life with regard to vital statistics as well as his relation to the period in which he thought and worked—giving the latter in as much detail as space permits. The selections that follow have been chosen for the most part, to amplify the thinker's central themes. Much of the material appears here in English translation for the first time. There are 375 references.

Here is Buddha, Confucius, Socrates, Aristotle, Galileo, Copernicus, Kant, Darwin, Mohammed, Newton, Plato, the Bacons, Pythagoras, Cicero, Spinoza, Dewey, and hundreds of others.

Truly this book could be called the Who's Who in Philosophy for all time. It will be invaluable as a reference work in philosophy.

REA, FREDERICK B. *Alcoholism.* New York (15 East 40th Street): Philosophical Library, 1956. 143 P. $3.50.

This book by an English writer proposes a new approach to temperance reform. The subtitle of the book is *Its Psychology and Cure.*

The writer discusses the complexity of the problem, the metabolism of alcohol, the types of persons who tend to become alcoholics, the road to alcoholism, possible methods of treatment, alcoholics anonymous, and possible treatments.

Altogether this is an excellent discussion and approach to a very serious world problem.

STARKEY, B. J. *Laplace Transforms for Electrical Engineers.* New York (15 East 40th Street): Philosophical Library, 1956. 279 P. $10.00.

This book for advanced engineers explains the method of solving linear differential equations.

ALEXANDER, H. G. *The Leibniz-Clarke Correspondence.* New York (15 East 40th Street): Philosophical Library, 1956. 200 P. $4.75.

This is the first complete publication in English since 1738 of the 1715–16 correspondence between Leibniz and Clarke. The controversy arose early between Newton and Leibniz over the significance and implication of Newton's new theories. Leibniz saw in the new theories a real threat to natural religion and many objections to Newton's idea. Some of these objections are still unresolved. Certain relevant passages of Newton's *Principia* and *Opticks* are included.

The correspondence consists of five papers by Leibniz and five replies by Samuel Clarke.

STONTENBURGH, JR., JOHN L. *Dictionary of Arts and Crafts.* New York (15 East 40th Street): Philosophical Library, 1956. 259 P. $6.00.

This is said to be the only dictionary of its kind. Included are not only terms used to describe an art or craft, but also the names of tools and their use and also their history or origin. Many techniques are also described.

This is a valuable book for those associated with arts and crafts industries and also interesting to many other persons.

THOMAS, MEINON, RAUSON, S. L. AND RICHARDSON, J. A. *Plant Physiology.* New York (15 East 40th Street): Philosophical Library, Inc., 1956. 692 P. $12.00.

This is the fourth revised edition of a text last revised in 1947. The text has been quite popular in Great Britain. The authors are professors and lecturers in Botany at King's College, Newcastle upon Tyne, in the University of Durham.

STEWART, DAVID A. *Preface to Empathy.* New York (15 East 40th Street): Philosophical Library, 1956. 157 P. $3.75.

Empathy is defined as the projection of one's own personality into the personality of another in order to understand him better or the intellectual identification of oneself with another. The author of this book maintains that empathy is thought to be the most important act in the life of human beings who aspire to be persons. To be emphatic is what it means to be or to become a person.

Empathy means not only to feel, think, and act like another person but also to learn how one differs from him. Psychologists should be especially interested in this discussion of the broad field of empathy.

SYMPOSIUM. *Precision Electrical Measurements.* New York (15 East 40th Street): Philosophical Library, 1956. $12.00.

This publication consists of 26 papers presented at an international Symposium held in November 1954 at the National Physical Laboratory, Teddington, Middlesex, England. Summarized discussions appear at the head of each part.

EDWARDS, ARTHUR C. *The Art of Melody.* New York (15 E. 40th Street): Philosophical Library, 1956. 266 P. $4.75.

The appreciation of a melody is a dynamic and aesthetic experience. This book formulates a sys-

tem of melodic construction which will unfold the potential of a musical idea according to the basic and enduring principles characteristic of all aesthetic forms. The criteria of repetition, contrast, climax, return and balance are these structural principles.

Stern, August P. *Classics in Biology.* New York (15 E. 40th Street): Philosophical Library. 1955. 337 P. $7.50.

This survey illuminates the high points of progress in the study of biology by providing fascinating glimpses of the philosophical theories which have been proposed in different ages up to our time. Many famous controversies are interestingly described. Teachers of biology, philosophy, and the history of science will find the book quite stimulating.

Osborne, A. K. *An Encyclopaedia of the Iron and Steel Industry.* New York (15 East 40th Street): Philosophical Library, 1956. 558 P. $25.00.

The purpose of this encyclopaedia is to provide a concise description of the materials, plants, tools, and processes used in the steel and iron industry and those industries closely associated with it, from the preparation of the ore, down to the finished product.

The book is intended primarily as a reference and not for use as a textbook. There is a very extensive bibliography. College chemistry libraries will especially find this a fine reference, probably the most comprehensive book of this kind ever published.

Hale, A. P. *Electrical Interference.* New York (15 E. 40th Street): Philosophical Library, 1956. 122 P. $4.75.

The General Post Office was called upon to investigate some 140,000 complaints of interference with radio and television reception in the year of 1954. When it is realized that many more complaints were settled without recourse to G.P.O., an idea may be obtained of the magnitude of the problem. The chief cause of the complaint is the wide range of high frequency noise, normally the result of operating electrical machinery. About 10 per cent results from inefficient earth or aerial installation at the receiving site. This book in some detail discusses the various sources of electrical interference.

Wagstaffe, Reginald and Fidler, J. Havelock. *The Preservation of Natural History Specimens, I: The Invertebrates.* New York (15 E. 40th Street): Philosophical Library, Inc., 1955. 204 P. $10.00.

This volume brings together up-to-date methods employed in the preservation of invertebrate specimens, methods described in diverse and scattered literature, often inaccessible to the reader.

The step-by-step methods employed by the authors will be appreciated by the professional biologist and can also be followed by the amateur naturalist.

Friedlander, C. P. and Priest, D. A. *Insects and Spiders.* New York (15 E. 40th Street): Philosophical Library, 1956. 124 P. $2.75.

This key covers about a hundred families of insects and seventy genera of spiders. A large number of drawings illustrate the characteristics of the groups described. The authors are teachers in English secondary schools.

Ellis, Rhoda. *Dictionary of Dietetics.* New York (15 E. 40th Street): Philosophical Library, 1956. 152 P. $6.00.

The *Dictionary of Dietitics* is a compilation of terms and references related to diet and diet therapy. The book should be of interest to both lay and professional people who are concerned about diets, nutrition, and foods as well as dietetics. It is an excellent reference for biology, food home economics teachers as well as teachers of nutrition and dietetics.

Sarles, William Bowen, Frazier, William Carroll, Wilson, Joe Bransford and Knight, Stanley Glenn. *Microbiology.* New York (49 East 33rd Street): Harper and Brothers, 1956. 491 P. $5.75.

This is the second edition of a text first published in 1951 after ten years of testing in successive mimeographed editions. Some 200 colleges have adopted it as a text, attesting to its popularity. The present edition represents a thorough revision.

Young, Clarence W., Stebbins, G. Ledyard and Brooks, Frank G. *Introduction to Biological Science.* New York (49 East 33rd Street): Harper & Brothers, 1956. 555 P. $4.75.

This is a new text based on the longer *The Human Organism and the World of Life* by Young and Stebbins. However it is not an abridged edition of this earlier volume. It is intended as a text for less intensive or shorter courses in general biology and for a survey or general college courses in the subject. The primary aim is to present a picture of the life processes in the human species and its relationship with that of the whole organic world.

There are some 250 figures, a complete glossary of biological terms at the end of each chapter, and also summary outlines for each chapter. This would seem to be an excellent basic text or reference, for a one semester course in college biology.

Hamilton, John Raymond and Hamilton, Walter T. *Mathematical Analysis.* New York (49 East 33rd Street): Harper and Brothers, 1956. 379 P. $7.50.

This text is designed for a first year course in college mathematics, especially for engineering

and physical science majors whose preparation is limited to elementary and intermediate algebra and plane geometry. It is directed toward preparing the student for entrance into a vigorous course in calculus the following year.

ANDRES, PAUL G., MISER, HIGH J. AND REINGOLD, HAIM. *Basic Mathematics for Science and Engineering.* New York (440 Fourth Avenue): John Wiley & Sons, Inc., 1955. 846 P. $6.75.

This text sets forth the topics from algebra, trigonometry, analytic geometry, and introductory calculus required for an intelligent pursuit of elementary science and engineering courses. The slide rule is explained early and used throughout, and so are trigonometric functions and vectors. Graphical methods are stressed. There are 650 worked out examples and over 7,000 exercises.

WOOD, JESSE HERMON AND KEENAN, CHARLES WILLIAM. *General College Chemistry.* New York (49 East 33rd Street): Harper and Brothers, 1957. 689 P. $6.50.

This college text is written to be read and understood by college freshmen of average preparation and with the belief that general chemistry most adequately serves the student's needs with respect to later specialization whether he goes into chemistry, engineering, home economics, agriculture, education or business.

The material has been so graded that it becomes progressively more difficult after the tenth chapter, leveling off at the end of the twenty-first chapter at which time the student is expected to have mastered the principles and fundamental concepts of chemical reaction.

This approach makes this a rather unique book which may prove unusually effective in the classroom.

HUTCHINSON, CHARLES A., RUTHLAND, JR., LEON W. AND VARNER, WALTER W. *Engineering Problems.* New York (49 East 33rd Street): Harper and Brothers, 1956. 179 P. $3.00.

This is an elementary text-workbook covering the applications of Mathematics to basic engineering topics, designed for a laboratory course in engineering mathematics.

WEIER, T. E., STOCKING, C. R. AND TUCKER, J. M. *Botany: A Laboratory Manual.* New York (440 Fourth Avenue): John Wiley and Sons, Inc., 1957. 175 P. $2.95.

This second revised edition of a loose-leaf laboratory manual is designed to accompany the authors' textbook reviewed above. Sixty exercises comprise the laboratory exercises.

ARNETT, JR., ROSS H. *Books on Zoology.* Rochester, New York (St. John Fisher College): Ross H. Arnett, Jr., 1956. 72 P. Free.

This book was prepared for the Society of Systematic Zoology by the author. Books are listed under divisions, such as natural history, physiology, genetics, ecology, conservation, entomology, and so on. There are 24 headings in all. Books are also listed by the publisher. There is an index to authors.

ROBBINS, WILFRED W., WEIER, T. ELLIOTT AND STOCKING, C. RALPH. *Botany: An Introduction to Plant Science.* New York (440 Fourth Avenue): John Wiley and Sons, Inc., 1957. 578 P. $6.95.

This is the second edition of a college textbook in botany, first published in 1950. This edition has been written by the two junior authors since Dr. Robbins passed away some time ago. The text is suitable for science majors. In addition, it would serve as a terminal course text for other students. The emphasis is on the plant as a whole as a living, functioning organism.

LINDGREN, HENRY CLAY. *Mental Health In Education.* New York (383 Madison): Henry Holt and Company, 1954. 561 P. $4.75.

The major theme of this book is that the central purpose of education is helping children to grow up to be adequate, effective, healthy, and happy adults. Many of the concepts and techniques discussed in the book may be new to most readers.

The first chapter develops the mental point of view in education and the next few chapters provide a background for understanding why children behave as they do. There follows chapters concerned with the relationship between the individual and the group. The role of the school in helping children and adolescents become socially, intellectually, and emotionally mature is discussed in following chapters. There is a chapter on evaluation and diagnosis and a final chapter on the teacher and his problems of adjustment.

Teachers at all levels will find this a most interesting and helpful book.

NEWMAN, EDWIN S. AND MARGOLIN, LEO J. *Fundraising Made Easy.* New York (42 West 16th Street): Oceana Publications, 1956. 158 P. $2.50.

Fundraising seems to have become an established American custom. There never seems to be a time that there isn't some drive going on—Community Chest, Salvation Army, Polio, Christmas Seals, Veteran posts, women's clubs, welfare agencies, scouts, churches, P.T.A., colleges, schools, band uniforms, school clubs, CARE packages, Hungarian Relief, Red Cross, Disasters, and what have you. A lot of people find themselves actively engaged in soliciting funds for one or more of the above or similar groups.

This book is replete with ideas as to how to more readily raise the above funds. Both group and individual practical fund raising techniques are suggested and discussed. Public relations are discussed in the second part of the book, including such media as radio, TV, newspapers, magazines, posters, advertising, and so on.

MOTT-SMITH, GEOFFREY. ***Mathematical Puzzles.*** New York (920 Broadway): Dover Publications, Inc., 1956. 248 P. $1.00.

Here are 188 mathematical puzzles for beginners and enthusiasts. There are puzzles for beginners with only a knowledge of beginning arithmetic, for those who understand algebra and plane geometry, and for the trained mathematician. Solutions worked out in detail are found at the close of the book.

KAUFMAN, GERALD LYNTON. *The Book of Modern Puzzles.* New York (920 Broadway): Dover Publications, Inc., 1956. 188 P. $1.00.

This is a collection of more than 100 word puzzles and puzzles involving logic. All are new. Here are word and sentence puzzles, Bull's Eyes and Dianagrams, Design and Drawing Puzzles, Playing Card Puzzles, Jabberwocky Brain-Teasers, Puzzles in Observation, Hit or Miscellaneous Problems, and Intelligence Tests.

If you enjoy puzzles, you will enjoy and have a good time with this book. Solutions are given in the book.

GARDNER, MARTIN. *Mathematics, Magic, and Mystery.* New York (920 Broadway): Dover Publications, Inc., 1956. 176 P. $1.00.

Material that has never before appeared in print is included in the 115 sections of magic tricks that depend upon mathematical principles. Mathematic enthusiasts, magic devotees, and puzzle fans will find here tricks to their heart's desire.

There are card tricks galore, magic made with common objects like dice, dominoes, calendars, watches, matches, dollar bills, handkerchiefs, string, rope, rubber bands, and tricks with pure numbers.

A lot of fun can be had from this book!

GAINES, HELEN FOUCHE. *Cryptanalysis.* New York (920 Broadway): Dover Publications, Inc., 1956. 236 P. $1.95.

This is a standard elementary and intermediate text for persons interested in modern scientific methods of enciphering and deciphering cryptograms. There is no repetition of ancient material but there is included much not generally known except to experts. Complete details and solutions are given.

A lot of people would like to send and receive messages in code. This could be the book they are looking for!

SMITH, LAWRENCE DWIGHT. *Cryptography.* New York (920 Broadway): Dover Publications, Inc., 1956. 164 P. $1.00.

This book on the science of secret writing gives the history and modern use of codes and ciphers, together with 151 problems and their solutions. Methods used in breaking ciphers and codes during World War II are described.

Have you ever had a hankering to do some secret writing on your own? This book will afford you a practical introduction.

KOGAN, ZUCE. *Essentials in Problem Solving.* New York (480 Lexington Avenue): Arco Publishing Company, Inc., 1956. 119 P. $3.00.

Essentials in Problem Solving proposes a method for problem solving which involves the formulation, adoption, and utilization of "approaches" that are directed toward meeting today's requirements. "Approaches" are a set of general solutions to be applied to specific problems in science, technology, and human relations. The purpose of these "approaches" is to reduce obstructions to thinking, lighten the task of problem solving, widen the scope of possible solutions, and to offer solutions to problems which previously seemed unsolvable. It is the author's belief that methods for the acquisition and use of knowledge have not kept pace with the expansion of knowledge.

The author is a consulting engineer and most of his examples of using "approaches" in problem-solving are taken from that area. He believes that essentials in problem-solving explained in this book can be applied to problem-solving in education as well.

FREILICH, ARTHUR AND SHAFRITZ, ARNOLD. *How to Win Tangled Names Contests.* New York (480 Lexington Avenue): Arco Publishing Company, Inc., 1956. 99 P. $3.00.

The authors won $10,000 each in such contests in the *New York Herald Tribune* and the *Philadelphia Bulletin.* A lot of fans wish they could! The authors present their explanations in step-by-step fashion from the first puzzle to the last one.

The book tells how contests are run, solving puzzles with a master list, solving tie-breakers, general theory of solution, trial and error solution, mathematical method, samples solved and lists provided.

CANCER REPORTS SECTION OF NATIONAL CANCER INSTITUTE. *Reading on Cancer: An Annotated Bibliography.* Washington, D. C.: Public Health Service, U. S. Department of Health, Education, and Welfare, 1955. 16 P. Free.

This pamphlet lists books, pamphlets, reports, articles in popular periodicals and professional journals, and other pertinent material. Each listing is indicated as either: easy reading (E), moderately difficult (M), or difficult (D).

There are 59 titles under books and pamphlets and 107 titles under articles, and 8 titles under book lists.

KETCHAM, HANK. *Dennis the Menace Rides Again.* New York: Pocket Books, Inc., 1956. $0.25.

Dennis the Menace fans, numbered in the millions, will thoroughly enjoy this fourth book of further misadventures of America's No. 1 expert of how to lose neighbors and annoy parents. The idea for the series came late in 1950, based on the antics of the cartoonist's real son, Dennis.